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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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Mitsuaki OSHIMA et al. :
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COMMUNICATION SYSTEM :
(Reissue Divisional
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CLAIM OF PRIORITY UNDER 35 U.S.C. 119

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

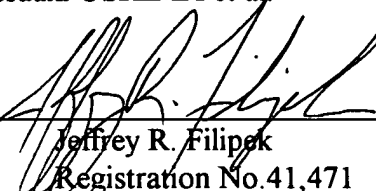
Patentees in the above-entitled application, by their agent, hereby claim the priority date under the International Convention of Japanese Application No. 3-62798 filed March 27, 1991, Japanese Application No. 3-95813 filed April 25, 1991, Japanese Application No. 3-155650 filed May 29, 1991, Japanese Application No. 3-182236 filed July 23, 1991, Japanese Application No. 4-60739 filed March 17, 1992, Japanese Application No. 5-132984 filed May 10, 1993, Japanese Application No. 5-261612 filed September 24, 1993, Japanese Application No. 5-349972 filed December 27, 1993, and Japanese Application No. 6-79668 filed March 24, 1994, acknowledged in the Declaration

of the subject application. A certified copy of the afore-mentioned priority document is of record in the patent file.

Respectfully submitted,

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VERIFICATION

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Sir:

I, Toshimine IDE, c/o Matsushita Electric Industrial Co., Ltd.,
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declare and say:

that, I am thoroughly conversant in both the Japanese and
English languages; and

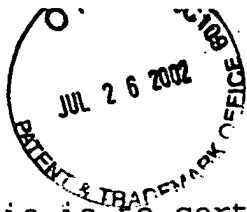
that I am presently engaged as a translator in these languages;

that the attached document represents a true English translation
of the Japanese Priority Application No. 3-095813 filed April 25, 1991.

I further declare that all statements made herein of my own
knowledge are true and that all statements made on information and
belief are believed to be true; and further that these statements were
made with the knowledge that willful false statements and the like so
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Signed this 27th day of June, 2002

Toshimine IDE



PATENT OFFICE

JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy of the following application as filed with this office.

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Application Number : 03-95813/1991

Applicant (s) : Matsushita Electric Industrial Co., Ltd.

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3rd April, 1992
Commissioner,
Patent Office

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SIGNAL TRANSMISSION SYSTEM

NUMBER OF CLAIMS:

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LIST OF ACCOMPANIED ITEMS:

Patent Specification	1
Drawing(s)	1
Abstract of the Disclosure	1

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[Document name] Specification

[Title of the invention] Signal transmission system

[Claims]

1. A signal transmission system for transmitting data comprising a signal input unit, a modulation unit for modulating two carriers orthogonal to each other by the input signal from the input unit and generating m signal points where $m \geq 5$ on a signal space diagram, and a transmission unit for transmitting a modulation signal, wherein a first data stream and a second data stream of n values are fed as the input signal, the signal points are divided into n signal point groups, the signal point groups are assigned to data of the first data stream individually, and the data of the second data group are assigned to the signal points in the signal point groups and transmitted.

2. A signal transmission system comprising an input unit of reception signal, a demodulator for demodulating QAM modulation signal of signal point of P value on a signal space diagram, and an output unit, wherein the signal point is divided into n signal point groups, a first data stream

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is demodulated by corresponding each signal point group to the n-value first data stream, a second data stream is demodulated by corresponding the P/n value second data stream to the individual P/n signal points in the signal point groups, and data in the first data stream and second data stream are demodulated and reproduced.

3. A signal transmission system for transmitting data comprising a signal input unit, a modulation unit for modulating plural carriers differing in phase by the input signal from the input unit and generating m signal points where $m \geq 5$ on a signal space diagram, and a transmission unit for transmitting a modulated signal, wherein a first data stream and a second data stream of n values are fed as the input signal, the signal points are divided into n signal point groups, the signal point groups are assigned to n-value data of the first data stream individually, the data in the second data group are assigned to the signal points of the signal point groups, the transmission signal is sent by a transmitter which transmits, the signal points are divided into n signal point groups by a reception apparatus

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comprising an input unit of the transmission signal, a demodulator for demodulating the QAM modulated wave of P-value signal point, and an output unit, and the first data stream of n value of each signal point group is corresponded and demodulated, and the second data stream of p/n value is corresponded to the signal point of p/n value in the signal point group and demodulated, and the data in the first data stream and second data stream are demodulated and reproduced by using the reception apparatus.

4. A signal transmission system of claim 1, wherein the video signal is separated into a high frequency band video signal and a low frequency band video signal, the low frequency band video signal is transmitted as the first data stream, and the high frequency band signal is transmitted as the second data stream.

5. A signal transmission system of claim 2, wherein the video signal is separated into a high frequency band video signal and a low frequency band video signal, the low frequency band video signal is transmitted as the first data stream, and the high frequency band signal is transmitted as

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the second data stream.

6. A signal transmission system of claim 3, wherein the video signal is separated into a high frequency band video signal and a low frequency band video signal, the low frequency band video signal is transmitted as the first data stream, and the high frequency band signal is transmitted as the second data stream.

7. A signal transmission system of claim 1, wherein both first data group and second data group may be created during transmission or reception, and when the code error rate of the second data group becomes high during transmission, the transmission or reception of the second data group is stopped, so that only the first data group is transmitted.

8. A signal transmission system of claim 2, wherein the operation may be limited to transmission of first data stream alone as required, if the code error rate of the second data stream becomes high while receiving both first data stream and second data stream.

9. A signal transmission system of claim 2, wherein a carrier reproducing unit for reproducing a carrier from

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reception signal is provided, and the carrier reproducing unit reproduces the carrier by multiplying the frequency of the reception signal by 16 times.

DETAILED DESCRIPTION OF THE INVENTION

Industrial Field of Utilization

The present invention relates to a signal transmission system for transmitting a digital signal by modulating two carriers orthogonal to each other.

Prior Art

Digital transmission systems are used widely in various fields recently. In particular, the advancement of satellite transmission technology is dramatic.

As a recent application, the image digital satellite transmission system comes to be noticed. The image digital satellite transmission apparatus is partly used as mobile repeating means for broadcasting stations at the present, and its application in satellite broadcasting is expected in future.

From the viewpoint of broadcasting, the public interest is important, and it is essential to keep the existing right of all viewers for a long period. Henceforth, broadcasting is demanded to present plural services in one channel. In this case, it is not permitted if one service in a same channel disturbs the other service. Compatibility of plural services is important.

On the other hand, to meet the needs of the viewers becoming more and more sophisticated, it is required to improve the broadcast services both in quality and in quantity by presenting, for example, HDTV broadcast, high quality music broadcast, information presenting broadcast and FAX broadcast. However, the assignment of broadcast channels is limited. Therefore it is required to increase the information quantity within a limited frequency range of broadcast channel.

Hence, forthcoming new transmission standards, such as digital TV broadcasting standards, are required to have extendability of information quantity to cope with the future social demands and technical progress and compatibil-

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ity with existing apparatus.

The conventional transmission system such as satellite transmission is reviewed here from the viewpoint of compatibility and extendability.

At the present, HDTV broadcasting is being studied as a new broadcasting service. The satellite broadcasting system of the mainstream HDTV is the analog system represented by MUSE system. These systems are hardly compatible with the existing NTSC broadcasting. Lately is proposed a method for broadcasting in 4 to 20 channels by using one transponder, as digital satellite broadcasting method, by compressing NTSC TV signals to 6 Mbps or less and multiplexing in the TDM system by using quaternary PSK modulation. In addition, as the HDTV broadcasting system, a method of compressing HDTV signal to data quantity of about 15 Mbps, and broadcasting is also proposed.

Problems that the Invention Is to Solve

In the proposed method of employing the conventional signal transmission system, in HDTV broadcasting, transmis-

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sion is effected merely by using 3 to 10 channels of NTSC. Accordingly, the NTSC channels occupied by the HDTV broadcasting cannot be received during HDTV broadcasting. The compatibility of the conventional NTSC and HDTV was not satisfactory. Besides, no consideration was given to the extendability of the information amount that may be required in the future.

The invention is to solve these problems of the prior art, and it is an object thereof to present a signal transmission system capable of realizing digital TV broadcasting, possessing compatibility of NTSC broadcasting the HDTV broadcasting, and extendability of NTSC broadcasting standard into HDTV broadcasting standard.

Means of Solving the Problems

To achieve the above object, the signal transmission system of the invention presents a transmission apparatus for transmitting data comprising a signal input unit, a modulation unit for modulating plural carriers differing in phase by the input signal from the input unit and generating

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m signal m points ($m \geq 5$) on a signal vector diagram, and a transmission unit for transmitting a modulated signal, and a reception apparatus comprising an input unit of the transmission signal, a demodulator for demodulating QAM modulated waves of signal point of one value on the vector diagram, and an output unit.

Operation of the Invention

In this constitution, a first data stream and a second data stream possessing n pieces of data are entered as input signal, and modulated waves of the QAM system of variable m values having signal points of m value on the vector diagram are prepared by the modulator of the transmission apparatus. Dividing these m signal points into n sets of signal point groups, and the signal point groups are assigned to n pieces of data of the first data stream, and the data of the second data stream are assigned to m/n signal points or sub signal point groups in the signal point groups, and transmission signals are sent out from the transmission apparatus. Depending on the case, third data may be also sent out.

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Next, in the reception apparatus possessing a demodulator of p values where $p > m$, the transmission signal is received, and p signal points are divided into n sets of signal point groups first with respect to the p signal points on the signal space diagram, then the signals of the first data stream are demodulated and reproduced. The first data and second data are demodulated and reproduced by demodulating by corresponding the second data stream of p/n values to the p/n signal points in the corresponding signal point groups. In the receiver where $p = n$, n signal point groups are reproduced, and corresponding to n values each, only the first data stream is demodulated and reproduced.

In this action, when same signals are received from the transmission apparatus, the first data stream and the second data stream are demodulated in a receiving having a large antenna and multiple demodulating capability. In the receiving having a small antenna and less demodulating capability, the first data stream is received. In this way, a compatible transmission system can be built up. In this case, by assigning the first data stream to the low frequen-

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cy band TV signals of low frequency band components of NTSC or HDTV, and the second data stream to the high frequency band TV signals of high frequency band components of HDTV or the like, the NTSC signal is received in the receiver having a less demodulating capability for same radio wave, while the HDTV signal is received in the receiver having a multiple demodulating capability. Thus, digital broadcasting compatible between NTSC and HDTV is realized.

PREFERRED EMBODIMENTS OF THE INVENTION

Embodiment 1

One embodiment of the present invention will be described referring to the relevant drawings.

Fig. 1 shows the entire arrangement of a signal transmission system according to the present invention. A transmitter 1 comprises an input unit 2, a divider circuit 3, a modulator 4, and a transmitter unit 5. In action, each input multiplex signal is divided by the divider circuit 3 into three groups, a first data stream D1, a second data stream D2, and a third data stream D3, which are then modu-

lated by the modulator 4 before transmitted from the transmitter unit 5. The modulated signal is sent up from an antenna 6 through an uplink 7 to a satellite 10 where it is intercepted by an uplink antenna 11 and amplified by a transponder 12 before transmitted from a downlink antenna 13 towards the ground.

The transmission signal is then sent down through three downlinks 21, 32, and 41 to a first 23, a second 33, and a third receiver 43 respectively. In the first receiver 23, the signal intercepted by an antenna 22 is fed through an input unit 24 to a demodulator 25 where its first data stream only is demodulated, while the second and third data streams are not recovered, before transmitted further from an output unit 26.

Similarly, the second receiver 33 allows the first and second data streams of the signal intercepted by an antenna 32 and fed from an input unit 34 to be demodulated by a demodulator 35 and then, summed by a summer 37 to a single data stream which is then transmitted further from an output unit 36.

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The third receiver 43 allows all the first, second, and third data streams of the signal intercepted by an antenna 42 and fed from an input unit 44 to be demodulated by a demodulator 45 and then, summed by a summer 47 to a single data stream which is then transmitted further from an output unit 46.

As understood, the three discrete receivers 23, 33, and 43 have their respective demodulators of different characteristics such that their outputs demodulated from the same frequency band signal of the transmitter 1 contain data of different sizes. More particularly, three different but compatible data can simultaneously be carried on a given frequency band signal to their respective receivers. For example, each of three, existing NTSC, HDTV, and super HDTV, digital signals is divided into a low, a high, and a super high frequency band components which represent the first, the second, and the third data stream respectively. Accordingly, the three different TV signals can be transmitted on a one-channel frequency band carrier for simultaneous reproduction of a medium, a high, and a super high resolution TV

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image respectively.

In service, the NTSC TV signal is intercepted by a receiver accompanied with a small antenna for demodulation of small-sized data, the HDTV signal is intercepted by a receiver accompanied with a medium antenna for demodulation of medium-sized data, and the super HDTV signal is intercepted by a receiver accompanied with a large antenna for demodulation of large-sized data. Also, as illustrated in Fig. 1, a digital NTSC TV signal containing only the first data stream for digital NTSC TV broadcasting service is fed to a digital transmitter 51 where it is received by an input unit 52 and modulated by a demodulator 54 before transmitted further from a transmitter unit 55. The demodulated signal is then sent up from an antenna 56 through an uplink 57 to the satellite 10 which in turn transmits the same through a downlink 58 to the first receiver 23 on the ground.

The first receiver 23 demodulates with its demodulator 24 the modulated digital signal supplied from the digital transmitter 51 to the original first data stream signal. Similarly, the same modulated digital signal can be inter-

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cepted and demodulated by the second 33 or third receiver 43 to the first data stream or NTSC TV signal. In summary, the three discrete receivers 23, 33, and 43 all can intercept and process a digital signal of the existing TV system for reproduction.

The arrangement of the signal transmission system will be described in more detail.

Fig. 2 is a block diagram of the transmitter 1, in which an input signal is fed across the input unit 2 and divided by the divider circuit 3 into three digital signals containing a first, a second, and a third data stream respectively.

Assuming that the input signal is a video signal, its low frequency band component is assigned to the first data stream, its high frequency band component to the second data stream, and its super-high frequency band component to the third data stream. The three different frequency band signals are fed to a modulator input 61 of the modulator 4. Here, a signal point modulating/changing circuit 67 modulates or changes the positions of the signal points accord-

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ing to an externally given signal. The modulator 4 is arranged for amplitude modulation on two 90° -out-of-phase carriers respectively which are then summed to a multiple QAM signal. More specifically, the signal from the modulator input 61 is fed to both a first 62 and a second AM modulator 63. Also, a carrier wave of $\cos(2\pi fct)$ produced by a carrier generator 64 is directly fed to the first AM modulator 62 and also, to a $\pi/2$ phase shifter 66 where it is 90° shifted in phase to a $\sin(2\pi fct)$ form prior to transmitted to the second AM modulator 63. The two amplitude modulated signals from the first and second AM modulators 62, 63 are summed by a summer 65 to a transmission signal which is then transferred to the transmitter unit 5 for output. This procedure is well known and will no further be explained.

The QAM signal will now be described in a common 8×8 or 16 state constellation referring to the first quadrant of a space diagram in Fig. 3. The output signal of the modulator 4 is expressed by a sum vector of two, $A\cos 2\pi fct$ and $B\cos 2\pi fct$, vectors 81, 82 which represent the two

90° -out-of-phase carriers respectively. When the distal point of a sum vector from the zero point represents a signal point, the 16 QAM signal has 16 signal points determined by a combination of four horizontal amplitude values a_1, a_2, a_3, a_4 and four vertical amplitude values b_1, b_2, b_3, b_4 . The first quadrant in Fig. 3 contains four signal points 83 at C_{11} , 84 at C_{12} , 85 at C_{22} , and 86 at C_{21} .

C_{11} is a sum vector of a vector $0-a_1$ and a vector $0-b_1$ and thus, expressed as $C_{11} = a_1 \cos 2\pi fct - b_1 \sin 2\pi fct = A \cos(2\pi fct + d\pi/2)$.

It is now assumed that the distance between 0 and a_1 in the orthogonal coordinates of Fig. 3 is A_1 , between a_1 and a_2 is A_2 , between 0 and b_1 is B_1 and between b_1 to b_2 is B_2 .

As shown in Fig. 4, the 16 signal points are allocated in vector coordinate, in which each point represents a four-bit pattern thus to allow the transmission of four bit data per period or time slot.

Fig. 5 illustrates a common assignment of two-bit patterns to the 16 signal points.

When the distance between two adjacent signal points is

great, it will be identified by the receiver with much ease. Hence, it is desired to space the signal points at greater intervals. If two particular signal points are allocated near to each other, they are rarely distinguished and error rate will be increased. Therefore, it is most preferred to have the signal points spaced at equal intervals as shown in Fig. 5, in which the 16 QAM signal is defined by $A_1 = A_2/2$.

The transmitter 1 of the embodiment is arranged to divide an input digital signal into a first, a second, and a third data or bit stream. The 16 signal points or groups of signal points are divided into four groups. Then, 4 two-bit patterns of the first data stream are assigned to the four signal point groups respectively, as shown in Fig. 6. More particularly, when the two-bit pattern of the first data stream is 11, one of four signal points of the first signal point group 91 in the first quadrant is selected depending on the content of the second data stream for transmission. Similarly, when 01, one signal point of the second signal point group 92 in the second quadrant is selected and transmitted. When 00, one signal point of the third signal point

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group 93 in the third quadrant is transmitted and when 10, one signal point of the fourth signal point group 94 in the fourth quadrant is transmitted. Also, 4 two-bit patterns in the second data stream of the 16 QAM signal, or e.g. 16 four-bit patterns in the second data stream of a 64-state QAM signal, are assigned to four signal points or sub signal point groups of each of the four signal point groups 91, 92, 93, 94 respectively, as shown in Fig. 7. It should be understood that the assignment is symmetrical between any two quadrants. The assignment of the signal points to the four groups 91, 92, 93, 94 is determined by priority to the two-bit data of the first data stream. As the result, two-bit data of the first data stream and two-bit data of the second data stream can be transmitted independently. Also, the first data stream will be demodulated with the use of a common 4 PSK receiver having a given antenna sensitivity. If the antenna sensitivity is higher, a modified type of the 16 QAM receiver of the present invention will intercept and demodulate both the first and second data streams with equal success.

Fig. 8 shows an example of the assignment of the first and second data streams in two-bit patterns.

When the low frequency band component of an HDTV video signal is assigned to the first data stream and the high frequency component to the second data stream, the 4 PSK receiver can produce an NTSC-level picture from the first data stream and the 16- or 64-state QAM receiver can produce an HDTV picture from a composite reproduction signal of the first and second data streams.

Since the signal points are allocated at equal intervals, there is developed in the 4 PSK receiver a threshold distance between the coordinate axes and the shaded area of the first quadrant, as shown in Fig. 9. If the threshold distance is A_{T0} , a 4 PSK signal having an amplitude of A_{T0} will successfully be intercepted. However, the amplitude has to be increased to a three times greater value or $3A_{T0}$ for transmission of a 16 QAM signal while the threshold distance A_{T0} being maintained. More particularly, the energy for transmitting the 16 QAM signal is needed nine times greater than that for sending the 4 PSK signal. Also,

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when the 4 PSK signal is transmitted in a 16 QAM mode, energy waste will be high and reproduction of a carrier signal will be troublesome. Above all, the energy available for satellite transmitting is not abundant but strictly limited to minimum use. Hence, no large-energy-consuming signal transmitting system will be put into practice until more energy for satellite transmission is available. It is expected that a great number of the 4 PSK receivers are introduced into the market as digital TV broadcasting is soon in service. After introduction to the market, the 4 PSK receivers will hardly be shifted to higher sensitivity models because a signal intercepting characteristic gap between the two, old and new, models is high. Therefore, the transmission of the 4 PSK signals must not be abandoned. In this respect, a new system is desperately needed for transmitting the signal point data of a quasi 4 PSK signal in the 16 QAM mode with the use of less energy. Otherwise, the limited energy at a satellite station will degrade the entire transmission system.

The present invention resides in a multiple signal

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level arrangement in which the four signal point groups 91, 92, 93, 94 are allocated at a greater distance from each other, as shown in Fig. 10, for minimizing the energy consumption required for 16 QAM modulation of quasi 4 PSK signals.

For clearing the relation between the signal receiving sensitivity and the transmitting energy, the arrangement of the digital transmitter 51 and the first receiver 23 will be described in more detail referring to Fig. 1.

Both the digital transmitter 51 and the first receiver 23 are formed of known types for data transmission or video signal transmission e.g. in TV broadcasting service. As shown in Fig. 17, the digital transmitter 51 is a 4 PSK transmitter equivalent to the multiple-bit QAM transmitter 1, shown in Fig. 2, without AM modulation capability. In operation, an input signal is fed through an input unit 52 to a modulator 54 where it is divided by a modulator input 121 to two components. The two components are then transferred to a first two-phase modulator circuit 122 for phase modulation of a base carrier and a second two-phase modula-

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tor circuit 123 for phase modulation of a carrier which is 90° out of phase with the base carrier respectively. Two outputs of the first and second two-phase modulator circuits 122, 123 are then summed by a summer 65 to a composite modulated signal which is further transferred from a transmitter unit 55.

The resultant modulated signal is shown in the space diagram of Fig. 18.

It is known that the four signal points are allocated at equal distances for achieving optimum energy utilization. Fig. 18 illustrates an example where the four signal points 125, 126, 127, 128 represent 4 two-bit patterns, 11, 01, 00, and 10 respectively. It is also desired for successful data transfer from the digital transmitter 51 to the first receiver 23 that the 4 PSK signal from the digital transmitter 51 has an amplitude of not less than a given level. More specifically, when the minimum amplitude of the 4 PSK signal needed for transmission from the digital transmitter 51 to the first receiver 23 of 4 PSK mode, or the distance between 0 and a_1 in Fig. 18 is A_{T0} , the first receiver 23 can suc-

cessfully intercept any 4 PSK signal having an amplitude of more than A_{T0} .

The first receiver 23 is arranged to receive at its small-diameter antenna 22 a desired or 4 PSK signal which is transmitted from the transmitter 1 or digital transmitter 51 respectively through the transponder 12 of the satellite 10 and demodulate it with the demodulator 24. In more particular, the first receiver 23 is substantially designed for interception of a digital TV or data communications signal of 4 PSK or 2 PSK mode.

Fig. 19 is a block diagram of the first receiver 23 in which an input signal received by the antenna 22 from the satellite 12 is fed through the input unit 24 to a carrier reproducing circuit 131 where a carrier wave is demodulated and to a $\pi/2$ phase shifter 132 where a 90° phase shifted carrier wave is demodulated. Also, two 90° -out-of-phase components of the input signal are detected by a first 133 and a second phase detector circuit 134 respectively and transferred to a first 136 and a second discrimination/demodulation circuit 137 respectively. Two demodulated

components from their respective discrimination/demodulation circuits 136 and 137, which have separately been discriminated at units of time slot by means of timing signals from a timing wave extracting circuit 135, are fed to a first data stream reproducing unit 232 where they are summed to a first data stream signal which is then delivered as an output from the output unit 26.

The input signal to the first receiver 23 will now be explained in more detail referring to the vector diagram of Fig. 20. The 4 PSK signal received by the first receiver 23 from the digital transmitter 51 is expressed in an ideal form without transmission distortion and noise, using four signal points 151, 152, 153, 154 shown in Fig. 20.

In practice, the real four signal points appear in particular extended areas about the ideal signal positions 151, 152, 153, 154 respectively due to noise, amplitude distortion, and phase error developed during transmission. If one signal point is unfavorably displaced from its original position, it will hardly be distinguished from its neighbor signal point and the error rate will thus be in-

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creased. As the error rate increases to a critical level, the reproduction of data becomes less accurate. For enabling the data reproduction at a maximum acceptable level of the error rate, the distance between any two signal points should be far enough to be distinguished from each other. If the distance is $2A_{R0}$, the signal point 151 of a 4 PSK signal at close to a critical error level has to stay in a first discriminating area 155 denoted by the hatching of Fig. 20 and determined by $|0-a_{R1}| \geq A_{R0}$ and $|0-b_{R1}| \geq A_{R0}$. This allows the signal transmission system to reproduce carrier waves and thus, demodulate a wanted signal. When the minimum radius of the antenna 22 is set to r_0 , the transmission signal of more than a given level can be intercepted by any receiver of the system. The amplitude of a 4 PSK signal of the digital transmitter 51 shown in Fig. 18 is minimum at A_{T0} and thus, the minimum amplitude A_{R0} of a 4 PSK signal to be received by the first receiver 23 is determined equal to A_{T0} . As the result, the first receiver 23 can intercept and demodulate the 4 PSK signal from the digital transmitter 51 at the maximum acceptable level of

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the error rate when the radius of the antenna 22 is more than r_0 . If the transmission signal is of modified 16- or 64-state QAM mode, the first receiver 23 may find difficult to reproduce its carrier wave. For compensation, the signal points are increased to eight which are allocated at angles of $(\pi/4 + n\pi/2)$ as shown in Fig. 25-a and its carrier wave will be reproduced by a 16x multiplication technique. Also, if the signal points are assigned to 16 locations at angles of $n\pi/8$ as shown in Fig. 25-b, the carrier of a quasi 4 PSK mode 16 QAM modulated signal can be reproduced with the carrier reproducing circuit 131 which is modified for performing 16x frequency multiplication. At the time, the signal points in the transmitter 1 should be arranged to satisfy $A_1/(A_1+A_2) = \tan(\pi/8)$.

The 16 PSK signal of the transmitter 1 will now be explained referring to the vector diagram of Fig. 9. When the horizontal vector distance A_1 of the signal point 83 is greater than A_{T0} of the minimum amplitude of the 4 PSK signal of the digital transmitter 51, the four signal points 83, 84, 85, 86 in the first quadrant of Fig. 9 stay in the

shaded or first 4 PSK signal receivable area 87. When received by the first receiver 23, the four points of the signal appear in the first discriminating area of the vector field shown in Fig. 20. Hence, any of the signal points 83, 84, 85, 86 of Fig. 9 can be translated into the signal level 151 of Fig. 20 by the first receiver 23 so that the two-bit pattern of 11 is assigned to a corresponding time slot. The two-bit pattern of 11 is identical to 11 of the first signal point group 91 or first data stream of a signal from the transmitter 1. Equally, the first data stream will be reproduced at the second, third, or fourth quadrant. As the result, the first receiver 23 reproduces two-bit data of the first data stream out of the plurality of data streams in a 16-, 32-, or 64-state QAM signal transmitted from the transmitter 1. The second and third data streams are contained in four segments of the signal point group 91 and thus, will not affect on the demodulation of the first data stream. They may however affect the reproduction of a carrier wave and an adjustment, described later, will be needed.

If the transponder of a satellite supplies an abundance

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of energy, the foregoing technique of 16 to 64-state QAM mode transmission will be feasible. However, the transponder of the satellite in any existing satellite transmission system is strictly limited in the power supply due to its compact size and the capability of solar batteries. If the transponder or satellite is increased in size thus weight, its launching cost will soar. This disadvantage will rarely be eliminated by traditional techniques unless the cost of launching a satellite rocket is reduced to a considerable level. In the existing system, a common communications satellite provides as low as 20W of power supply and a common broadcast satellite offers 100W to 200W at best. For transmission of such a 4 PSK signal in the symmetrical 16-state QAM mode as shown in Fig. 9, the minimum signal point distance is needed $3A_{T0}$ as the 16 QAM amplitude is expressed by $2A_1 = A_2$. Thus, the energy needed for the purpose is nine times greater than that for transmission of a common 4 PSK signal, in order to maintain compatibility. Also, any conventional satellite transponder can hardly provide a power for enabling such a small antenna of the 4 PSK first

receiver to intercept a transmitted signal therefrom. For example, in the existing 40W system, 360W is needed for appropriate signal transmission and will be unrealistic in the respect of cost.

It would be understood that the symmetrical signal state QAM technique is most effective when the receivers equipped with the same sized antennas are employed corresponding to a given transmitting power. Another novel technique will however be preferred for use with the receivers equipped with different sized antennas.

In more detail, while the 4 PSK signal can be intercepted by a common low cost receiver system having a small antenna, the 16 QAM signal is intended to be received by a high cost, high quality, multiple-bit modulating receiver system with a medium or large sized antenna which is designed for providing highly valuable services, e.g. HDTV entertainments, to a particular person who invests more money. This allows both 4 PSK and 16 QAM signals, if desired, with a 64 DMA, to be transmitted simultaneously with the help of a small increase in the transmitting power.

For example, the transmitting power can be maintained low when the signal points are allocated at $A_1 = A_2$ as shown in Fig. 10. The amplitude $A(4)$ for transmission of 4 PSK data is expressed by a vector 96 equivalent to a square root of $2A_1^2$. The amplitude $A(16)$ of the entire signal is expressed by a vector 96 equivalent to a square root of $(A_1+A_2)^2 + (B_1+B_2)^2$. Then,

$$|A(4)|^2 = A_1^2 + B_1^2 = A_{TO}^2 + A_{TO}^2 = 2A_{TO}^2$$

$$|A(16)|^2 = (A_1+A_2)^2 + (B_1+B_2)^2 = 4A_{TO}^2 + 4A_{TO}^2 = 8A_{TO}^2$$

$$|A(16)| / |A(4)| = 2$$

Accordingly, the 16 QAM signal can be transmitted at a two times greater amplitude and a four times greater transmitting energy than those needed for the 4 PSK signal. A modified 16 QAM signal according to the present invention will not be demodulated by a common receiver designed for symmetrical, equally distanced signal point QAM. However, it can be demodulated with the second receiver 33 when two thresholds A_1 and A_2 are predetermined to appropriate values. At Fig. 10, the minimum distance between two signal points in the first segment of the signal point group 91 is

A_1 and $A_2/2A_1$ is established as compared with the distance $2A_1$ of 4 PSK. Then, as $A_1 = A_2$, the distance becomes $1/2$. This explains that the signal receiving sensitivity has to be two times greater for the same error rate and four times greater for the same signal level. For having a four times greater value of sensitivity, the radius r_2 of the antenna 32 of the second receiver 33 has to be two times greater than the radius r_1 of the antenna 22 of the first receiver 23 thus satisfying $r_2 = 2r_1$. For example, the antenna 32 of the second receiver 33 is 60 cm in diameter when the antenna 22 of the first receiver 23 is 30 cm. In this manner, the second data stream representing the high frequency component of an HDTV signal will be carried on a single channel and demodulated successfully. As the second receiver 33 intercepts the second data stream or a higher data signal, its owner can enjoy a return of his higher investment. Hence, the second receiver 33 of a higher price may be accepted. As the minimum energy for transmission of 4 PSK data is predetermined, the ratio n_{16} of modified 16 APSK transmitting energy to 4 PSK transmitting energy will be calculated

to the antenna radius r_2 of the second receiver 33 using a ratio between A_1 and A_2 shown in Fig. 10.

In particular, n_{16} is expressed by $((A_1 + A_2)/A_1)^2$ which is the minimum energy for transmission of 4 PSK data. As the signal point distance suited for modified 16 QAM interception is A_2 , the signal point distance for 4 PSK interception is $2A_1$, and the signal point distance ratio is $A_2/2A_1$, the antenna radius r_2 is determined as shown in Fig. 11, in which the curve 101 represents the relation between the transmitting energy ratio n_{16} and the radius r_2 of the antenna 22 of the second receiver 23.

Also, the point 102 indicates transmission of common 16 QAM at the equal distance signal state mode where the transmitting energy is nine times greater and thus will no more be practical. As apparent from the graph of Fig. 11, the antenna radius r_2 of the second receiver 23 cannot be reduced further even if n_{16} is increased more than 5 times.

The transmitting energy at the satellite is limited to a small value and thus, n_{16} preferably stays not more than 5 times the value, as denoted by the hatch of Fig. 11. The

point 104 within the hatching area 103 indicates, for example, that the antenna radius r_2 of a two times greater value is matched with a 4x value of the transmitting energy.

Also, the point 105 represents that the transmission energy should be doubled when r_2 is about 5x greater. Those values are all within a feasible range.

The value of n_{16} not greater than 5x value is expressed using A_1 and A_2 as:

$$n_{16} = ((A_1 + A_2)/A_1)^2 \leq 5$$

Hence, $A_2 \leq 1.23A_1$.

If the distance between any two signal point group segments shown in Fig. 10 is $2A(4)$ and the maximum amplitude is $2A(16)$, $A(4)$ and $A(16)-A(4)$ are proportional to A_1 and A_2 respectively. Hence, $(A(16))^2 \leq 5 (A(14))^2$ is established.

The action of a modified 64 ASPK transmission will be described as the third receiver 43 can perform 64-state QAM demodulation.

Fig. 12 is a vector diagram in which each signal point group segment contains 16 signal points as compared with 4 signal points of Fig. 10. The first signal point group

segment 91 in Fig. 12 has a 4x4 matrix of 16 signal points allocated at equal intervals including the point 170. For providing compatibility with 4 PSK, $A_1 \geq A_{T0}$ has to be satisfied. If the radius of the antenna 42 of the third receiver 43 is r_3 and the transmitting energy is n_{64} , the equation is expressed as:

$$r_3^2 = \{6^2/(n-1)\}r_1^2$$

This relation between r_3 and n of a 64 QAM signal is also shown in the graphic representation of Fig. 13.

It is understood that the signal point assignment shown in Fig. 12 allows the second receiver 33 to demodulate only two-bit patterns of 4 PSK data. Hence, it is desired for having compatibility between the first, second, and third receivers that second receiver 33 is arranged capable of demodulating a modified 16 QAM form from the 64 QAM modulated signal.

The compatibility between the three discrete receivers can be implemented by three-level grouping of signal points, as illustrated in Fig. 14. The description will be made referring to the first quadrant in which the first signal

point group segment 91 represents the two-bit pattern 11 of the first data stream.

In particular, a first sub segment 181 in the first signal point group segment 91 is assigned the two-bit pattern 11 of the second data stream. Equally, a second 182, a third 183, and a fourth sub segment 184 are assigned 01, 00, and 10 of the same respectively. This assignment is identical to that shown in Fig. 7.

The signal point allocation of the third data stream will now be explained referring to the vector diagram of Fig. 15 which shows the first quadrant. As shown, the four signal points 201, 205, 209, 213 represent the two-bit pattern of 11, the signal points 202, 206, 210, 214 represent 01, the signal points 203, 207, 211, 215 represent 00, and the signal points 204, 208, 212, 216 represent 10. Accordingly, the two-bit patterns of the third data stream can be transmitted separately of the first and second data streams. In other words, two-bit data of the three different signal levels can be transmitted respectively.

As understood, the present invention permits not only

transmission of six-bit data but also interception of three, two-bit, four-bit, and six-bit, different bit length data with their respective receivers while the signal compatibility remains between three levels.

The signal point allocation for providing compatibility between the three levels will be described.

As shown in Fig. 15 $A_1 \geq A_{T0}$ is essential for allowing the first receiver 23 to receive the first data stream.

It is needed to space any two signal points from each other by such a distance that the sub segment signal points, e.g. 182, 183, 184, of the second data stream shown in Fig. 15 can be distinguished from the signal point 91 shown in Fig. 10.

Fig. 15 shows that they are spaced by $2/3A_2$. In this case, the distance between the two signal points 201 and 202 in the first sub segment 181 is $A_2/6$. The transmitting energy needed for signal interception with the third receiver 43 is now calculated. If the radius of the antenna 32 is r_3 and the needed transmitting energy is n_{64} times the 4 PSK transmitting energy, the equation is expressed as:

$$r_3^2 = (12r_1)^2/(n-1)$$

This relation is also denoted by the curve 211 in Fig. 16.

For example, if the transmitting energy is 6 or 9 times greater than that for 4 PSK transmission at the point 223 or 222, the antenna 32 having a radius of 8x or 6x value respectively can intercept the first, second, and third data streams for demodulation. As the signal point distance of the second data stream is close to $2/3A_2$, the relation between r_1 and r_2 is expressed by:

$$r_2^2 = (3r_1)^2/(n-1)$$

Therefore, the antenna 32 of the second receiver 33 has to be a bit increased in radius as denoted by the curve 223.

As understood, while the first and second data streams are transmitted through a traditional satellite which provides a small signal transmitting energy, the third data stream can also be transmitted through a future satellite which provides a greater signal transmitting energy without interrupting the action of the first and second receivers 23, 33 or with no need of modification of the same and thus, both the compatibility and the advancement will highly be

ensured.

The signal receiving action of the second receiver 33 will first be described. As compared with the first receiver 23 arranged for interception with a smaller radius r_1 antenna and demodulation of the 4 PSK modulated signal of the digital transmitter 51 or the first data stream of the signal of the transmitter 1, the second receiver 33 is adapted for perfectly demodulating the 16 signal state two-bit data, shown in Fig. 10, or second data stream of the 16 QAM signal from the transmitter 1. In total, four-bit data including also the first data stream can be demodulated. The ratio between A_1 and A_2 is however different in the two transmitters. The two different data are loaded to a demodulation controller 231 of the second receiver 33, shown in Fig. 21, which in turn supplies their respective threshold values to the demodulating circuit for AM demodulation.

The block diagram of the second receiver 33 in Fig. 21 is similar in basic construction to that of the first receiver 23 shown in Fig. 19. The difference is that the radius r_2 of the antenna 32 is greater than r_1 of the anten-

na 22. This allows the second receiver 33 to identify a signal component involving a smaller signal point distance. The demodulator 35 of the second receiver 33 also contains a first 232 and a second data stream reproducing unit 233 in addition to the demodulation controller 231. There is provided a first discrimination/reproduction circuit 136 for AM demodulation of modified 16 QAM signals. As understood, each carrier is a four-bit signal having two, positive and negative, threshold values about the zero level. As apparent from the vector diagram of Fig. 22, the threshold values are varied depending on the transmitting energy of a transmitter since the transmitting signal of the embodiment is a modified 16 QAM signal. When the reference threshold is TH_{16} , it is determined by, as shown in Fig. 22:

$$TH_{16} = (A_1 + A_2/2) / (A_1 + A_2)$$

The various data for demodulation including A_1 and A_2 or TH_{16} , and the value m for multiple-bit modulation are also transmitted from the transmitter 1 as carried in the first data stream. The demodulation controller 231 may be arranged for recovering such demodulation data through

statistic process of the received signal.

If the demodulation data is lost, the demodulation of the second data stream will hardly be executed. This will be explained referring to a flow chart shown in Fig. 24.

Even if the demodulation data is not available, demodulation of the 4 PSK at Step 313 and of the first data stream at Step 301 can be implemented. At Step 302, the demodulation data retrieved by the first data stream reproducing unit 232 is transferred to the demodulation controller 231. If m is 4 or 2 at Step 303, the demodulation controller 231 triggers demodulation of 4 PSK or 2 PSK at Step 313. If not, the procedure moves to Step 310. At Step 305, two threshold values TH_8 and TH_{16} are calculated. The threshold value TH_{16} for AM demodulation is fed at Step 306 from the demodulation controller 231 to both the first 136 and the second discrimination/reproduction circuit 137. Hence, demodulation of the modified 16 QAM signal and reproduction of the second data stream can be carried out at Steps 307 and 315 respectively. At Step 308, the error rate is examined and if high, the procedure returns to Step 313 for

repeating the 4 PSK demodulation.

As shown in Fig. 22, the signal points 85, 83 are aligned on a line at an angle of $\cos(\omega t + n\pi/2)$ while 84 and 86 are off the line. Hence, the feedback of a second data stream transmitting carrier wave data from the second data stream reproducing unit 233 to a carrier reproducing circuit 131 is carried out so that no carrier needs to be extracted at the timing of the signal points 84 and 86.

The transmitter 1 is arranged to transmit carrier timing signals at intervals of a given time with the first data stream for the purpose of compensation for no demodulation of the second data stream. The carrier timing signal enables to identify the signal points 83 and 85 of the first data stream regardless of demodulation of the second data stream. Hence, the reproduction of carrier wave can be triggered by the transmitting carrier data to the carrier reproducing circuit 131.

It is then examined at Step 304 of the flow chart of Fig. 24 whether m is 16 or not upon receipt of such a modified 64 QAM signal as shown in Fig. 23. At Step 310, it is

also examined whether m is more than 64 or not. If it is determined at Step 311 that the received signal has no equal distance signal point constellation, the procedure goes to Step 312. The signal point distance TH_{64} of the modified 64 QAM signal is calculated from:

$$TH_{64} = (A_1 + A_2 / 2) / (A_1 + A_2)$$

This calculation is equivalent to that of TH_{16} but its resultant distance between signal points is smaller.

If the signal point distance in the first sub segment 181 is A_3 , the distance between the first 181 and the second sub segment 182 is expressed by $(A_2 - 2A_3)$. Then, the average distance is $(A_2 - 2A_3) / (A_1 + A_2)$ which is designated as d_{64} . When d_{64} is smaller than T_2 which represents the signal point discrimination capability of the second receiver 33, any two signal points in the segment will hardly be distinguished from each other. This judgement is executed at Step 313. If d_{64} is out of a permissive range, the procedure moves back to Step 313 for 4 PSK mode demodulation. If d_{64} is within the range, the procedure advances to Step 305 for allowing the demodulation of 16 QAM at Step 307. If it is

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determined at Step 308 that the error rate is too high, the procedure goes back to Step 313 for 4 PSK mode demodulation.

When the transmitter 1 supplies a modified 8 QAM signal such as shown in Fig. 25-a in which all the signal points are at angles of $\cos(2\pi f + n \cdot \pi / 4)$, the carrier waves of the signal are lengthened to the same phase and will thus be reproduced with much ease. At the time, two-bit data of the first data stream are demodulated with the 4-PSK receiver while one-bit data of the second data stream is demodulated with the second receiver 33 and the total of three-bit data can be reproduced.

The third receiver 43 will be described in more detail. Fig. 26 shows a block diagram of the third receiver 43 similar to that of the second receiver 33 in Fig. 21. The difference is that a third data stream reproducing unit 234 is added and also, the discrimination/reproduction circuit has a capability of identifying eight-bit data. The antenna 42 of the third receiver 43 has a radius r_3 greater than r_2 thus allowing smaller distance state signals, e.g. 32- or 64-state QAM signals, to be demodulated. For demodulation

of the 64 QAM signal, the first discrimination/reproduction circuit 136 has to identify 8 digit levels of the detected signal in which seven different threshold levels are involved. As one of the threshold values is zero, three are contained in the first quadrant.

Fig. 27 shows a space diagram of the signal in which the first quadrant contains three different threshold values.

As shown in Fig. 27, when the three normalized threshold values are $TH1_{64}$, $TH2_{64}$, and $TH3_{64}$, they are expressed by:

$$TH1_{64} = (A_1 + A_3/2) / (A_1 + A_2)$$

$$TH2_{64} = (A_1 + A_2/2) / (A_1 + A_2) \text{ and}$$

$$TH3_{64} = (A_1 + A_2 - A_3/2) / (A_1 + A_2).$$

Through AM demodulation of a phase detected signal using the three threshold values, the third data stream can be reproduced like the first and second data streams explained with Fig. 21. The third data stream contains e.g. four signal points 201, 202, 203, 204 at the first sub segment 181 shown in Fig. 23 which represent 4 values of

two-bit pattern. Hence, six digits or modified 64 QAM signals can be demodulated.

The demodulation controller 231 detects the values m , A_1 , A_2 , and A_3 from the demodulation data contained in the first data stream demodulated at the first data stream reproducing unit 232 and calculates the three threshold values $TH1_{64}$, $TH2_{64}$, and $TH3_{64}$ which are then fed to the first 136 and the second discrimination/reproduction circuit 137 so that the modified 64 QAM signal is demodulated with certainty. Also, if the demodulation data have been scrambled, the modified 64 QAM signal can be demodulated only with a specific or subscriber receiver. Fig. 28 is a flow chart showing the action of the demodulation controller 231 for modified 64 QAM signals. The difference from the flow chart for demodulation of 16 QAM shown in Fig. 24 will be explained. The procedure moves from Step 304 to Step 320 where it is examined whether $m=32$ or not. If $m=32$, demodulation of 32 QAM signals is executed at Step 322. If not, the procedure moves to Step 321 where it is examined whether $m=64$ or not. If yes, A_3 is examined at Step 323. If A_3 is

smaller than a predetermined value, the procedure moves to Step 305 and the same sequence as of Fig. 24 is implemented. If it is judged at Step 323 that A_3 is not smaller than the predetermined value, the procedure goes to Step 324 where the threshold values are calculated. At Step 325, the calculated threshold values are fed to the first and second discrimination/reproduction circuits and at Step 326, the demodulation of the modified 64 QAM signal is carried out. Then, the first, second, and third data streams are reproduced at Step 327. At Step 328, the error rate is examined. If the error rate is high, the procedure moves to Step 305 where the 16 QAM demodulation is repeated and if low, the demodulation of the 64 QAM is continued.

The action of carrier wave reproduction needed for execution of a satisfactory demodulating procedure will now be described. The scope of the present invention includes reproduction of the first data stream of a modified 16 or 64 QAM signal with the use of a 4 PSK receiver. However, a common 4 PSK receiver rarely reconstructs carrier waves, thus failing to perform a correct demodulation. For compen-

sation, some arrangement are necessary at both the transmitter and receiver sides.

Two techniques for the compensation are provided according to the present invention. A first technique relates to transmission of signal points aligned at angles of $(2n-1)\pi/4$ at intervals of a given time. A second technique offers transmission of signal points arranged at intervals of an angle of $n\pi/8$.

According to the first technique, the eight signal points including 83 and 85 are aligned at angles of $\pi/4$, $3\pi/4$, $5\pi/4$, and $7\pi/4$, as shown in Fig. 38. In action, at least one of the eight signal points is transmitted during sync time slot periods 452, 453, 454, 455 arranged at equal intervals of a time in a time slot gap 451 shown in the time chart of Fig. 38. Any desired signal points are transmitted during the other time slots. The transmitter 1 is also arranged to assign a data for the time slot interval to the sync timing data region 499 of a sync data block, as shown in Fig. 41.

The content of a transmitting signal will be explained

in more detail referring to Fig. 41. The time slot group 451 containing the sync time slots 452, 453, 454, 455 represents a unit data stream or block 491 carrying a data of D_n .

The sync time slots in the signal are arranged at equal intervals of a given time determined by the time slot interval or sync timing data. Hence, when the arrangement of the sync time slots is detected, reproduction of carrier waves will be executed slot by slot through extracting the sync timing data from their respective time slots.

Such a sync timing data S is contained in a sync block 493 accompanied at the front end of a data frame 492, which is consisted of a number of the sync time slots denoted by the hatching in Fig. 41. Accordingly, the data to be extracted for carrier wave reproduction are increased, thus allowing the 4 PSK receiver to reproduce desired carrier waves at higher accuracy and efficiency.

The sync block 493 comprises sync data regions 496, 497, 498, --- containing sync data S_1 , S_2 , S_3 , --- respectively which include unique words and demodulation data. The phase sync signal assignment region 499 is accompanied

at the end of the sync block 493, which holds a data of I_T including information about interval arrangement and assignment of the sync time slots.

The signal point data in the phase sync time slot has a particular phase and can thus be reproduced by the 4 PSK receiver. Accordingly, I_T in the phase sync signal assignment region 499 can be retrieved without error thus ensuring the reproduction of carrier waves at accuracy.

As shown in Fig. 41, the sync block 493 is followed by a demodulation data block 501 which contains demodulation data about threshold voltages needed for demodulation of the modified multiple-bit QAM signal. This data is essential for demodulation of the multiple-bit QAM signal and may preferably be contained in a region 502 which is a part of the sync block 493 for ease of retrieval.

Fig. 42 shows the assignment of signal data for transmission of burst form signals through a TDMA method.

The assignment is distinguished from that of Fig. 41 by the fact that a guard period 521 is inserted between any two adjacent D_n data blocks 491, 491 for interruption of the

signal transmission. Also, each data block 491 is accompanied at front end a sync region 522 thus forming a data block 492. During the sync region 522, the signal points at a phase of $(2n-1)\pi/4$ are only transmitted. Accordingly, the carrier wave reproduction will be feasible with the 4 PSK receiver. More specifically, the sync signal and carrier waves can be reproduced through the TDMA method.

The carrier wave reproduction of the first receiver 23 shown in Fig. 19 will be explained in more detail referring to Figs. 43 and 44. As shown in Fig. 43, an input signal is fed through the input unit 24 to a sync detector circuit 541 where it is sync detected. A demodulated signal from the sync detector 541 is transferred to an output circuit 542 for reproduction of the first data stream. A data of the phase sync signal assignment data region 499 (shown in Fig. 41) is retrieved with an extracting timing controller circuit 543 so that the timing of sync signals of $(2n-1)\pi/4$ data can be acknowledged and transferred as a phase sync control pulse 561 shown in Fig. 44 to a carrier reproduction controlling circuit 544. Also, the demodulated signal of

the sync detector circuit 541 is fed to a frequency multiplier circuit 545 where it is 4x multiplied prior to transmitted to the carrier reproduction controlling circuit 544. The resultant signal denoted by 562 in Fig. 44 contains a true phase data 563 and other data. As illustrated in a time chart 564 of Fig. 44, the phase sync time slots 452 carrying the $(2n-1)\pi/4$ data are also contained at equal intervals. At the carrier reproducing controlling circuit 544, the signal 562 is sampled by the phase sync control pulse 561 to produce a phase sample signal 565 which is then converted through sample-hold action to a phase signal 566. The phase signal 566 of the carrier reproduction controlling circuit 544 is fed across a loop filter 546 to a VCO 547 where its relevant carrier wave is reproduced. The reproduced carrier is then sent to the sync detector circuit 541. In this manner, the signal point data of the $(2n-1)\pi/4$ phase denoted by the shaded areas in Fig. 39 is recovered and utilized so that a correct carrier wave can be reproduced by 4x or 16x frequency multiplication. Although a plurality of phases are reproduced at the time, the absolute

phase of the carrier can successfully be identified with the use of a unique word assigned to the sync region 496 shown in Fig. 41.

For transmission of a modified 64 QAM signal such as shown in Fig. 40, signal points in the phase sync areas 471 at the $(2n-1)\pi/4$ phase denoted by the hatching are assigned to the sync time slots 452, 452b, etc. Its carrier can be reproduced hardly with a common 4 PSK receiver but successfully with the first receiver 23 of 4 PSK mode provided with the carrier reproducing circuit of the embodiment.

The foregoing carrier reproducing circuit is of COSTAS type. A carrier reproducing circuit of reverse modulation type will now be explained according to the embodiment.

Fig. 45 shows a reverse modulation type carrier reproducing circuit according to the present invention, in which a received signal is fed from the input unit 24 to a sync detector circuit 541 for producing a demodulated signal. Also, the input signal is delayed by a first delay circuit 591 to a delay signal. The delay signal is then transferred to a quadrature phase modulator circuit 592 where it is

reverse demodulated by the demodulated signal from the sync detector circuit 541 to a carrier signal. The carrier signal is fed through a carrier reproduction controller circuit 544 to a phase comparator 593. A carrier wave produced by a VCO 547 is delayed by a second delay circuit 594 to a delay signal which is also fed to the phase comparator 593. At the phase comparator 594, the reverse demodulated carrier signal is compared in phase with the delay signal thus producing a phase difference signal. The phase difference signal is sent through a loop filter 546 to the VCO 547 which in turn produces a carrier wave arranged in phase with the received carrier wave. In the same manner as of the COSTAS carrier reproducing circuit shown in Fig. 43, an extracting timing controller circuit 543 performs sampling of signal points contained in the hatching areas of Fig. 39. Accordingly, the carrier wave of a 16 or 64 QAM signal can be reproduced with the 4 PSK demodulator of the first receiver 23.

The reproduction of a carrier wave by 16x frequency multiplication will be explained. The transmitter 1 shown

in Fig. 1 is arranged to modulate and transmit a modified 16 QAM signal with assignment of its signal points at $n\pi/8$ phase as shown in Fig. 46. At the first receiver 23 shown in Fig. 19, the carrier wave can be reproduced with its COSTAS carrier reproduction controller circuit containing a 16x multiplier circuit 661 shown in Fig. 48. The signal points at each $n\pi/8$ phase shown in Fig. 46 are processed at the first quadrant by the action of the 16x multiplier circuit 661, whereby the carrier will be reproduced by the combination of a loop filter 546 and a VCO 541. Also, the absolute phase may be determined from 16 different phases by assigning a unique word to the sync region.

The arrangement of the 16x multiplier circuit will be explained referring to Fig. 48. A sum signal and a difference signal are produced from the demodulated signal by an adder circuit 662 and a subtracter circuit 663 respectively and then, multiplied each other by a multiplier 664 to a $\cos 2\theta$ signal. Also, a multiplier 665 produces a $\sin 2\theta$ signal. The two signals are then multiplied by a multiplier 666 to a $\sin 4\theta$ signal.

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Similarly, a $\sin 8\theta$ signal is produced from the two, $\sin 2\theta$ and $\cos 2\theta$, signals by the combination of an adder circuit 667, a subtracter circuit 668, and a multiplier 670. Furthermore, a $\sin 16\theta$ signal is produced by the combination of an adder circuit 671, a subtracter circuit 672, and a multiplier 673. Then, the $16x$ multiplication is completed.

Through the foregoing $16x$ multiplication, the carrier wave of all the signal points of the modified 16 QAM signal shown in Fig. 46 will successfully be reproduced without extracting particular signal points.

However, reproduction of the carrier wave of the modified 64 QAM signal shown in Fig. 47 can involve an increase in the error rate due to dislocation of some signal points from the sync areas 471.

Two techniques are known for compensation for the consequences. One is inhibiting transmission of the signal points dislocated from the sync areas. This causes the total amount of transmitted data to be reduced but allows the arrangement to be facilitated. The other is providing

the sync time slots as described in Fig. 38. In more particular, the signal points in the $n\pi/8$ sync phase areas, e.g. 471 and 471a, are transmitted during the period of the corresponding sync time slots in the time slot group 451. This triggers an accurate synchronizing action during the period thus minimizing phase error.

As now understood, the 16x multiplication allows the simple 4 PSK receiver to reproduce the carrier wave of a modified 16 or 64 QAM signal. Also, the insertion of the sync time slots causes the phasic accuracy to be increased during the reproduction of carrier waves from a modified 64 QAM signal.

As set forth above, the signal transmission system of the present invention is capable of transmitting a plurality of data on a single carrier wave simultaneously in the multiple signal level arrangement.

More specifically, three different level receivers which have discrete characteristics of signal intercepting sensitivity and demodulating capability are provided in relation to one single transmitter so that any one of them

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can be selected depending on a wanted data size to be demodulated which is proportional to the price. When the first receiver of low resolution quality and low price is acquired together with a small antenna, its owner can intercept and reproduce the first data stream of a transmission signal. When the second receiver of medium resolution quality and medium price is acquired together with a medium antenna, its owner can intercept and reproduce both the first and second data streams of the signal. When the third receiver of high resolution quality and high price is acquired with a large antenna, its owner can intercept and reproduce all the first, second, and third data streams of the signal.

If the first receiver is a home-use digital satellite broadcast receiver of low price, it will overwhelmingly be welcome by a majority of viewers. The second receiver accompanied with the medium antenna costs more and will be accepted by not common viewers but particular people who wants to enjoy HDTV services. The third receiver accompanied with the large antenna at least before the satellite output is increased, is not appropriated for home use and

will possibly be used in relevant industries. For example, the third data stream carrying super HDTV signals is transmitted via a satellite to subscriber cinemas which can thus play video tapes rather than traditional movie films and run movie business at lower cost.

When the present invention is applied to a TV signal transmission service, three different quality pictures are carried on one single channel wave and will offer compatibility with each other. Although the first embodiment refers to a 4 PSK, a modified 8 QAM, a modified 16 QAM, and a modified 64 QAM signal, other signals will also be employed with equal success including a 32 QAM, a 256 QAM, an 8 PSK, a 16 PSK, a 32 PSK signal. It would be understood that the present invention is not limited to a satellite transmission system and will be applied to a terrestrial communications system or a cable transmission system.

Embodiment 2

A second embodiment of the present invention will be described referring to the relevant drawings.

Fig. 29 is a schematic total view illustrating the

second embodiment in the form of a digital TV broadcasting system. An input video signal 402 of super high resolution TV image is fed to an input unit 403 of a first video encoder 401. Then, the signal is divided by a divider circuit 404 into three, first, second, and third, data streams which are transmitted to a compressing circuit 405 for data compression before further delivered.

Equally, other three input video signals 406, 407, and 408 are fed to a second 409, a third 410, and a fourth video encoder 411 respectively which all are arranged identical in construction to the first video encoder 401 for data compression.

The four first data streams from their respective encoders 401, 409, 410, 411 are transferred to a first multiplexer 413 of a multiplexer 412 where they are time multiplexed by TDM process to a first data stream multiplex signal which is fed to a transmitter 1.

A part or all of the four second data streams from their respective encoders 401, 409, 410, 411 are transferred to a second multiplexer 414 of the multiplexer 412 where

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they are time multiplexed to a second data stream multiplex signal which is then fed to the transmitter 1. Also, a part or all the four third data streams are transferred to a third multiplexer 415 where they are time multiplexed to a third data stream multiplex signal which is then fed to the transmitter 1.

The transmitter 1 performs modulation of the three data stream signals with its modulator 4 by the same manner as described in the first embodiment. The modulated signals are sent from a transmitter unit 5 through an antenna 6 and an uplink 7 to a transponder 12 of a satellite 10 which in turn transmits it to three different receivers including a first receiver 23.

The modulated signal transmitted through a downlink 21 is intercepted by a small antenna 22 having a radius r_1 and fed to a first data stream reproducing unit 232 of the first receiver 23 where its first data stream only is demodulated. The demodulated first data stream is then converted by a first video decoder 421 to a traditional 425 or wide-picture NTSC or video output signal 426 of low image resolution.

Also, the modulated signal transmitted through a down-link 31 is intercepted by a medium antenna 32 having a radius r_2 and fed to a first 232 and a second data stream reproducing unit 233 of a second receiver 33 where its first and second data streams are demodulated respectively. The demodulated first and second data streams are then summed and converted by a second video decoder 422 to an HDTV or video output signal 427 of high image resolution and/or to the video output signals 425 and 426.

Also, the modulated signal transmitted through a down-link 41 is intercepted by a large antenna 42 having a radius r_3 and fed to a first 232, a second 233, and a third data stream reproducing unit 234 of a third receiver 43 where its first, second, and third data streams are demodulated respectively. The demodulated first, second, and third data streams are then summed and converted by a third video decoder 423 to a super HDTV or video output signal 428 of super high resolution for use in a video theater or cinema. The video output signals 425, 426, and 427 can also be reproduced if desired. A common digital TV signal is trans-

mitted from a conventional digital transmitter 51 and when intercepted by the first receiver 23, will be converted to the video output signal 426 such as a low resolution NTSC TV signal.

The first video encoder 401 will now be explained in more detail referring to the block diagram of Fig. 30. An input video signal of super high resolution is fed through the input unit 403 to the divider circuit 404 where it is divided into four components by sub-band coding process. In more particular, the input video signal is separated through passing a horizontal lowpass filter 451 and a horizontal highpass filter 452 of e.g. QMF mode to two, low and high, horizontal frequency components which are then subsampled to a half of their quantities by two subsamplers 453 and 454 respectively. The low horizontal component is filtered by a vertical lowpass filter 455 and a vertical highpass filter 456 to a low horizontal low vertical component or $H_L V_L$ signal and a low horizontal high vertical component or $H_L V_H$ signal respectively. The two, $H_L V_L$ and $H_L V_H$, signals are then subsampled to a half by two subsampler 457 and 458

respectively and transferred to the compressing circuit 405.

The high horizontal component is filtered by a vertical lowpass filter 459 and a vertical highpass filter 460 to a high horizontal low vertical component or H_HV_L signal and a high horizontal high vertical component or H_HV_H signal respectively. The two, H_HV_L and H_HV_H , signals are then subsampled to a half by two subsampler 461 and 462 respectively and transferred to the compressing circuit 405.

H_LV_L signal is preferably DCT compressed by a first compressor 471 of the compressing circuit 405 and transmitted from a first output 405 as the first data stream.

Also, H_LV_H signal is compressed by a second compressor 473 and fed to a second output 464. H_HV_L signal is compressed by a third compressor 463 and fed to the second output 464. H_HV_H signal is divided by a divider 465 into two, high resolution (H_HV_H1) and super high resolution (H_HV_H2), video signals which are then transferred to the second output 464 and a third output 468 respectively.

The first video decoder 421 will now be explained in more detail referring to Fig. 31. The first data stream or

D_1 signal of the first receiver 23 is fed through an input unit 501 to a descrambler 502 of the first video decoder 421 where it is descrambled. The descrambled D_1 signal is expanded by an expander 503 to $H_L V_L$ which is then fed to an aspect ratio changing circuit 504. Thus, $H_L V_L$ signal can be delivered through and output unit 505 as a standard 500, letterbox format 507, wide-screen 508, or sidepanel format NTSC signal 509. The scanning format may be of non-interlace or interlace type and its NTSC mode lines may be 525 or doubled to 1050 by double tracing. When the received signal from the digital transmitter 51 is a digital TV signal of 4 PSK mode, it can also be converted by the first receiver 23 and the first video decoder 421 to a TV picture. The second video decoder 422 will be explained in more detail referring to the block diagram of Fig. 32. The D_1 signal of the second receiver 33 is fed through a first input 521 to a first expander 522 for data expansion and then, transferred to an oversampler 523 where it is sampled at $2x$. The oversampled signal is filtered by a vertical lowpass filter 524 to $H_L V_L$. Also, the D_2 signal of the second receiver 33 is

fed through a second input 530 to a divider 531 where it is divided into three components which are then transferred to a second 532, a third 533, and a fourth expander 534 respectively for data expansion. The three expanded components are sampled at 2x by three oversamplers 535, 536, 537 and filtered by a vertical highpass 538, a vertical lowpass 539, and a vertical highpass filter 540 respectively. Then, $H_L V_L$ from the vertical lowpass filter 524 and $H_L V_H$ from the vertical highpass filter 538 are summed by an adder 525, sampled by an oversampler 541, and filtered by horizontal lowpass filter 542 to a low frequency horizontal video signal. $H_H V_L$ from the vertical lowpass filter 539 and $H_H V_H$ from the vertical highpass filter 540 are summed by an adder 526, sampled by an oversampler 544, and filtered by horizontal highpass filter 545 to a high frequency horizontal video signal. The two, high and low frequency, horizontal video signal are then summed by an adder 543 to a high resolution video signal HD which is further transmitted through an output unit 546 as a video output 547 of e.g. HDTV format. If desired, a traditional NTSC video output can be recon-

structed with equal success.

Fig. 33 is a block diagram of the third video decoder 423 in which the D_1 and D_2 signals are fed through a first 521 and a second input 530 respectively to a high frequency band video decoder circuit 527 where they are converted to an HD signal by the same manner as above described. The D_3 signal is fed through a third input 551 to a super high frequency band video decoder circuit 552 where it is expanded, descrambled, and composed to H_HV_H2 signal. The HD signal of the high frequency band video decoder circuit 527 and the H_HV_H2 signal of the super high frequency band video decoder circuit 552 are summed by a summer 553 to a super high resolution TV or S-HD signal which is then delivered through an output unit 554 as a super resolution video output 555.

The action of multiplexing in the multiplexer 412 shown in Fig. 29 will be explained in more detail. Fig. 34 illustrates a data assignment in which the three, first, second, and third, data streams D_1 , D_2 , D_3 contain in a period of T six NTSC channel data $L1$, $L2$, $L3$, $L4$, $L5$, $L6$, six HDTV

channel data M1, M2, M3, M4, M5, M6 and six S-HDTV channel data H1, H2, H3, H4, H5, H6 respectively. In action, the NTSC or D_1 signal data L1 to L6 are time multiplexed by TDM process during the period T. More particularly, $H_L V_L$ of D_1 is assigned to a domain 601 for the first channel. Then, a difference data M1 between HDTV and NTSC or a sum of $H_L V_H$, $H_H V_L$, and $H_H V_H1$ is assigned to a domain 602 for the first channel. Also, a difference data H1 between HDTV and super HDTV or $H_H V_H2$ (See Fig. 30) is assigned to a domain 603 for the first channel.

The selection of the first channel TV signal will now be described. When intercepted by the first receiver 23 with a small antenna coupled to the first video decoder 21, the first channel signal is converted to a standard or widescreen NTSC TV signal as shown in Fig. 31. When intercepted by the second receiver 33 with a medium antenna coupled to the second video decoder 422, the signal is converted by summing L1 of the first data stream D_1 assigned to the domain 601 and M1 of the second data stream D_2 assigned to the domain 602 to an HDTV signal of the first

channel equivalent in program to the NTSC signal.

When intercepted by the third receiver 43 with a large antenna coupled to the third video decoder 423, the signal is converted by summing L1 of D_1 assigned to the domain 601, M1 of D_2 assigned to the domain 602, and H1 of D_3 assigned to the domain 603 to a super HDTV signal of the first channel equivalent in program to the NTSC signal. The other channel signals can be reproduced in an equal manner.

Fig. 35 shows another data assignment in which L1 of a first channel NTSC signal is assigned to a first domain 601. The domain 601 which is allocated at the front end of the first data stream D_1 , also contains at front a data S11 including a descrambling data and the demodulation data described in the first embodiment. A first channel HDTV signal is transmitted as L1 and M1. M1 which is thus a difference data between NTSC and HDTV is assigned to two domains 602 and 611 of D_2 . If L1 is a compressed NTSC component of 6 Mbps, M1 is as two times higher as 12 Mbps. Hence, the total of L1 and M1 can be demodulated at 18 Mbps with the second receiver 33 and the second video decoder

423. According to current data compression techniques, HDTV compressed signals can be reproduced at about 15 Mbps. This allows the data assignment shown in Fig. 35 to enable simultaneous reproduction of an NTSC and an HDTV first channel signal. However, this assignment allows no second channel HDTV signal to be carried. S21 is a descrambling data in the HDTV signal. A first channel super HDTV signal component comprises L1, M1, and H1. The difference data H1 is assigned to three domains 603, 612, and 613 of D_3 . If the NTSC signal is 6 Mbps, the super HDTV is carried at as high as 36 Mbps. When a compression rate is increased, super HDTV video data of about 2000 scanning line for reproduction of a cinema size picture for commercial use can be transmitted with an equal manner.

Fig. 36 shows a further data assignment in which H1 of a super HDTV signal is assigned to six time domains. If a NTSC compressed signal is 6 Mbps, this assignment can carry as nine times higher as 54 Mbps of D_3 data. Accordingly, super HDTV data of higher picture quality can be transmitted.

The foregoing data assignment makes the use of one of two, horizontal and vertical, polarization planes of a transmission wave. When both the horizontal and vertical polarization planes are used, the frequency utilization will be doubled. This will be explained below.

Fig. 49 shows a data assignment in which D_{V1} and D_{H1} are a vertical and a horizontal polarization signal of the first data stream respectively, D_{V2} and D_{H2} are a vertical and a horizontal polarization signal of the second data stream respectively, and D_{V3} and D_{H3} are a vertical and a horizontal polarization signal of the third data stream respectively. The vertical polarization signal D_{V1} of the first data stream carries a low frequency band or NTSC TV data and the horizontal polarization signal D_{H1} carries a high frequency band or HDTV data. When the first receiver 23 is equipped with a vertical polarization antenna, it can reproduce only the NTSC signal. When the first receiver 23 is equipped with an antenna for both horizontally and vertically polarized waves, it can reproduce the HDTV signal through summing L1 and M1. More specifically, the first

receiver 23 can provide compatibility between NTSC and HDTV with the use of a particular type antenna.

Fig. 50 illustrates a TDMA method in which each data burst 721 is accompanied at front a sync data 731 and a card data 471. Also, a frame sync data 720 is provided at the front of a frame. Like channels are assigned to like time slots. For example, a first time slot 750 carries NTSC, HDTV and super HDTV data of the first channel simultaneously. The six time slots 750, 750a, 750b, 750c, 750d, 750e are arranged independent from each other. Hence, each station can offer NTSC, HDTV, and/or super HDTV services independently of the other stations through selecting a particular channel of the time slots. Also, the first receiver 23 can reproduce an NTSC signal when equipped with a horizontal polarization antenna and both NTSC and HDTV signals when equipped with a compatible polarization antenna. In this respect, the second receiver 33 can reproduce a super HDTV at lower resolution while the third receiver 43 can reproduce a full super HDTV signal. According to the second embodiment, a compatible signal transmission system

will be constructed. It is understood that the data assignment is not limited to the burst mode TDMA method shown in Fig. 50 and another method such as time division multiplexing of continuous signals as shown in Fig. 49 will be employed with equal success. Also, a data assignment shown in Fig. 51 will permit a HDTV signal to be reproduced at high resolution.

As set forth above, the compatible digital TV signal transmission system of the second embodiment can offer three, super HDTV, HDTV, and conventional NTSC, TV broadcast services simultaneously. In addition, a video signal intercepted by a commercial station or cinema can be electronized.

Embodiment 3

A third embodiment of the present invention will be described referring to the relevant drawings.

Fig. 37 illustrates the entire arrangement of a signal transmission system of the third embodiment, which is arranged for terrestrial service and similar in both construction and action to that of the second embodiment shown in

Fig. 29. The difference is that the transmitter antenna 6 is replaced with a terrestrial antenna 6a and the receiver antennas 22, 32, 42 are replaced with also three terrestrial antennas 22a, 32a, 42a. The action of the system is identical to that of the second embodiment and will no more be explained. The terrestrial broadcast service unlike a satellite service depends much on the distance between the transmitter antenna 6a to the receiver antenna 22a, 32a, 42a. If a receiver is located far from the transmitter, the level of a received signal is low. Particularly, a common multi-level QAM signal can hardly be demodulated by the receiver which thus reproduces no TV program.

The signal transmission system of the present invention allows the first receiver 23 equipped with the antenna 22a, which is located at a far distance as shown in Fig. 37, to intercept a modified 16 or 64 QAM signal and demodulate at 4 PSK mode the first data stream or D_1 component of the received signal to an NTSC video signal so that a TV program picture of medium resolution can be displayed even if the level of the received signal is relatively low.

Also, the second receiver 33 with the antenna 32a is located at a medium distance from the antenna 6a and can thus intercept and demodulate both the first and second data streams or D_1 and D_2 components of the modified 16 or 64 QAM signal to an HDTV video signal which in turn produces an HDTV program picture.

The third receiver 43 with the antenna 42a is located at a near distance and can intercept and demodulate the first, second, and third data streams or D_1 , D_2 , and D_3 components of the modified 16 or 64 QAM signal to a super HDTV video signal which in turn produces a super HDTV picture equal in quality to a common movie picture.

The assignment of frequencies is determined by the same manner as of the time division multiplexing shown in Figs. 34, 35, and 36. Like Fig. 34, when the frequencies are assigned to first to sixth channels, L_1 of the D_1 component carries an NTSC data of the first channel, M_1 of the D_2 component carries an HDTV difference data of the first channel, and H_1 of the D_3 component carries a super HDTV difference data of the first channel. Accordingly, NTSC,

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HDTV, and super HDTV data all can be carried on the same channel. If D_2 and D_3 of the other channels are utilized as shown in Figs. 35 and 36, more data of HDTV and super HDTV respectively can be transmitted for higher resolution display.

As understood, the system allows three different but compatible digital TV signals to be carried on a single channel or using D_2 and D_3 regions of the other channels. Also, the medium resolution TV picture data of each channel can be intercepted in a wider service area according to the present invention.

A variety of terrestrial digital TV broadcast systems employing a 16 QAM HDTV signal of 6 MHz bandwidth have been proposed. Those are however not compatible with the existing NTSC system and thus, have to be associated with a simulcast technique for transmitting NTSC signals of the same program on another channel. Also, such a common 16 QAM signal limits a service area. The terrestrial service system of the present invention allows a receiver located at a relatively far distance to intercept successfully a medium

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resolution TV signal with no use of an additional device nor an extra channel.

The transmission method of the invention is to enhance the frequency utilization efficiency, but the power utilization efficiency is considerably lowered in certain receivers. It is, therefore, not applicable to all transmission systems. For example, in the satellite communication system for specific users, the most economical way is to change to the apparatus having the maximum frequency and power utilization efficiency available at the time depending on the technical innovation, and it is not always required to employ this invention.

In the case of, on the other hand, satellite communication appliances and broadcasting system for household use or small companies, the technique of the invention is required. It is because the satellite broadcasting standard is required to persist more than scores of years. In this period of scores of years, the standard, or the frequency band is not changed, but the transmission electric power of the satellite will be outstandingly improved. In this case,

scores of years later, the broadcasting station is responsible for the requirement that the programs should be received even by the existing appliances manufactured at the end of the twentieth century.

From this viewpoint, the invention emphasizes the frequency efficiency, rather than the power efficiency, and the electric power of the transmitter is not increased so much by setting several reception sensitivities at the receiver side, and therefore it is possible to transmit by the present satellite, and compatible plural pieces of information can be transmitted simultaneously. If the transmission electric power is increased, since it is possible to transmit in the same standard, the future extendability and compatibility with the existing appliances are guaranteed. Hence, as described herein, the invention brings about notable effects when applied in the future broadcasting standards or the like.

Effects of the Invention

Thus, according to the invention, in the transmission

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apparatus for transmitting data comprising a signal input unit, a modulation unit for modulating plural carriers differing in phase and generating m signal points on a signal vector diagram, and a transmission unit for transmitting a modulated signal, a first data stream and a second data stream of n values are entered, the signal is divided into n signal point groups to assign to the data of the first data stream of the signal point groups, while the data of the second data group are assigned to the signal points in the signal point groups, and the signal is transmitted by a transmitter which transmits a signal, and the signal is divided into n signal point groups in a reception apparatus comprising an input unit of the transmission signal, a demodulator for demodulating the QAM modulated wave of p signal points on the signal space diagram, and an output unit, and the first data stream of n values of signal point groups are modulated by corresponding, the data of the second data stream of p/n values are demodulated and reproduced to p/n signal points in the signal point groups, and the data is transmitted by using the reception apparatus.

and hence, by the modulator 4 of the transmitter 1, for example, the n -value first data stream, second data stream and third data stream are assigned to the signal point groups, and modified m -value QAM modulation signal is transmitted, and in the first receiver 23, by demodulating the n -value first data stream by the demodulator 25, the first data stream and second data stream in the second receiver 33, and the first data stream, second data stream and third data stream in the third receiver 43, therefore, a compatible and extendable signal transmission system is obtained which is capable of demodulating n -value data even in the receiver having the capacity of demodulating the n -value where $n < m$ from the multiple modulated wave modulated from the maximum m -value data.

By transmitting the NTSC signal as first data stream, and the differential signal of HDTV and NTSC as second data stream, NTSC broadcast and HDTV broadcast are compatible, and digital broadcasting of high extendability of information quantity is realized, which are notable effects.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view of the entire arrangement of a signal transmission system showing a first embodiment of the present invention;

Fig. 2 is a block diagram of a transmitter of the first embodiment;

Fig. 3 is a vector diagram showing a transmission signal of the first embodiment;

Fig. 4 is a vector diagram showing a transmission signal of the first embodiment;

Fig. 5 is a view showing an assignment of binary codes to signal points according to the first embodiment;

Fig. 6 is a view showing an assignment of binary codes to signal point groups according to the first embodiment;

Fig. 7 is a view showing an assignment of binary codes to signal points in each signal point group according to the first embodiment;

Fig. 8 is a view showing another assignment of binary codes to signal point groups and their signal points according to the first embodiment;

Fig. 9 is a view showing threshold values of the signal point groups according to the first embodiment;

Fig. 10 is a vector diagram of a modified 16 QAM signal of the first embodiment;

Fig. 11 is a graphic diagram showing the relation between antenna radius r_2 and transmission energy ratio n according to the first embodiment;

Fig. 12 is a view showing the signal points of a modified 64 QAM signal of the first embodiment;

Fig. 13 is a graphic diagram showing the relation between antenna radius r_3 and the transmission energy ratio n according to the first embodiment;

Fig. 14 is a vector diagram showing signal point groups and their signal points of the modified 64 QAM signal of the first embodiment;

Fig. 15 is an explanatory view showing the relation between A_1 and A_2 of the modified 64 QAM signal of the first embodiment;

Fig. 16 is a graphic diagram showing the relation between antenna radius r_2 , r_3 and transmission energy ratio

n_{16} , n_{64} respectively according to the first embodiment;

Fig. 17 is a block diagram of a digital transmitter of the first embodiment;

Fig. 18 is a signal space diagram of a 4 PSK modulated signal of the first embodiment;

Fig. 19 is a block diagram of a first receiver of the first embodiment;

Fig. 20 is a signal space diagram of a 4 PSK modulated signal of the first embodiment;

Fig. 21 is a block diagram of a second receiver of the first embodiment;

Fig. 22 is a vector diagram of a modified 16 QAM signal of the first embodiment;

Fig. 23 is a vector diagram of a modified 64 QAM signal of the first embodiment;

Fig. 24 is a flow chart showing an action of the first embodiment;

Figs. 25-a and 25-b are vector diagrams showing an 8 and a 16 QAM signal of the first embodiment respectively;

Fig. 26 is a block diagram of a third receiver of the

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first embodiment;

Fig. 27 is a view showing signal points of the modified 64 QAM signal of the first embodiment;

Fig. 28 is a flow chart showing another action of the first embodiment;

Fig. 29 is a schematic view of the entire arrangement of a signal transmission system showing a third embodiment of the present invention;

Fig. 30 is a block diagram of a first video encoder of the third embodiment;

Fig. 31 is a block diagram of a first video decoder of the third embodiment;

Fig. 32 is a block diagram of a second video decoder of the third embodiment;

Fig. 33 is a block diagram of a third video decoder of the third embodiment;

Fig. 34 is an explanatory view showing a time multiplexing of D_1 , D_2 and D_3 signals according to the third embodiment;

Fig. 35 is an explanatory view showing another time

multiplexing of the D_1 , D_2 , and D_3 signals according to the third embodiment;

Fig. 36 is an explanatory view showing a further time multiplexing of the D_1 , D_2 , and D_3 signals according to the third embodiment;

Fig. 37 is a schematic view of the entire arrangement of a signal transmission system showing a fourth embodiment of the present invention;

Fig. 38 is a vector diagram of a modified 16 QAM signal of the third embodiment;

Fig. 39 is a vector diagram of the modified 16 QAM signal of the third embodiment;

Fig. 40 is a vector diagram of a modified 64 QAM signal of the third embodiment;

Fig. 41 is a diagram of assignment of data components on a time base according to the third embodiment;

Fig. 42 is a diagram of assignment of data components on a time base in TDMA action according to the third embodiment;

Fig. 43 is a block diagram of a carrier reproducing

circuit of the third embodiment;

Fig. 44 is a diagram showing the principle of carrier wave reproduction according to the third embodiment;

Fig. 45 is a block diagram of a carrier reproducing circuit for reverse modulation of the third embodiment;

Fig. 46 is a diagram showing an assignment of signal points of the 16 QAM signal of the third embodiment;

Fig. 47 is a diagram showing an assignment of signal points of the 64 QAM signal of the third embodiment;

Fig. 48 is a block diagram of a carrier reproducing circuit for 16x multiplication of the third embodiment;

Fig. 49 is an explanatory view showing a time multiplexing of D_{V1} , D_{H1} , D_{V2} , D_{H2} , D_{V3} , and D_{H3} signals according to the third embodiment;

Fig. 50 is an explanatory view showing a TDMA time multiplexing of the D_{V1} , D_{H1} , D_{V2} , D_{H2} , D_{V3} , and D_{H3} signals according to the third embodiment;

Fig. 51 is an explanatory view showing another TDMA time multiplexing of the D_{V1} , D_{H1} , D_{V2} , D_{H2} , D_{V3} , and D_{H3} signals according to the third embodiment;

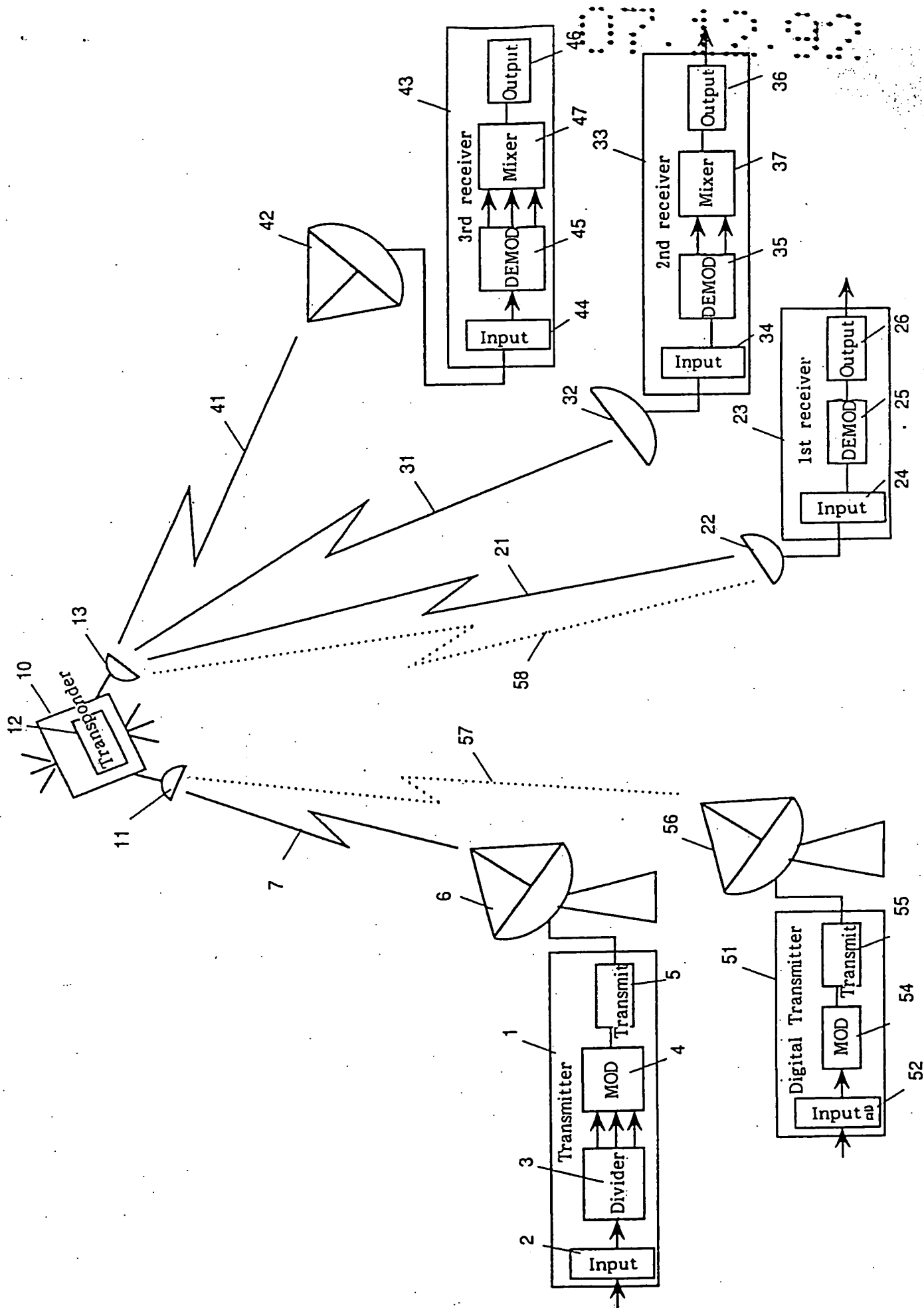
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Reference Numerals

- 1 Transmitter
- 4 Modulator
- 6 Antenna
- 6a Terrestrial antenna
- 10 Satellite
- 12 Repeater
- 23 First receiver
- 25 Demodulator
- 33 Second receiver
- 35 Demodulator
- 43 Third receiver
- 51 Digital transmitter
- 85 Signal point
- 91 First division signal point group
- 401 First image encoder



FIG. 1



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FIG.2

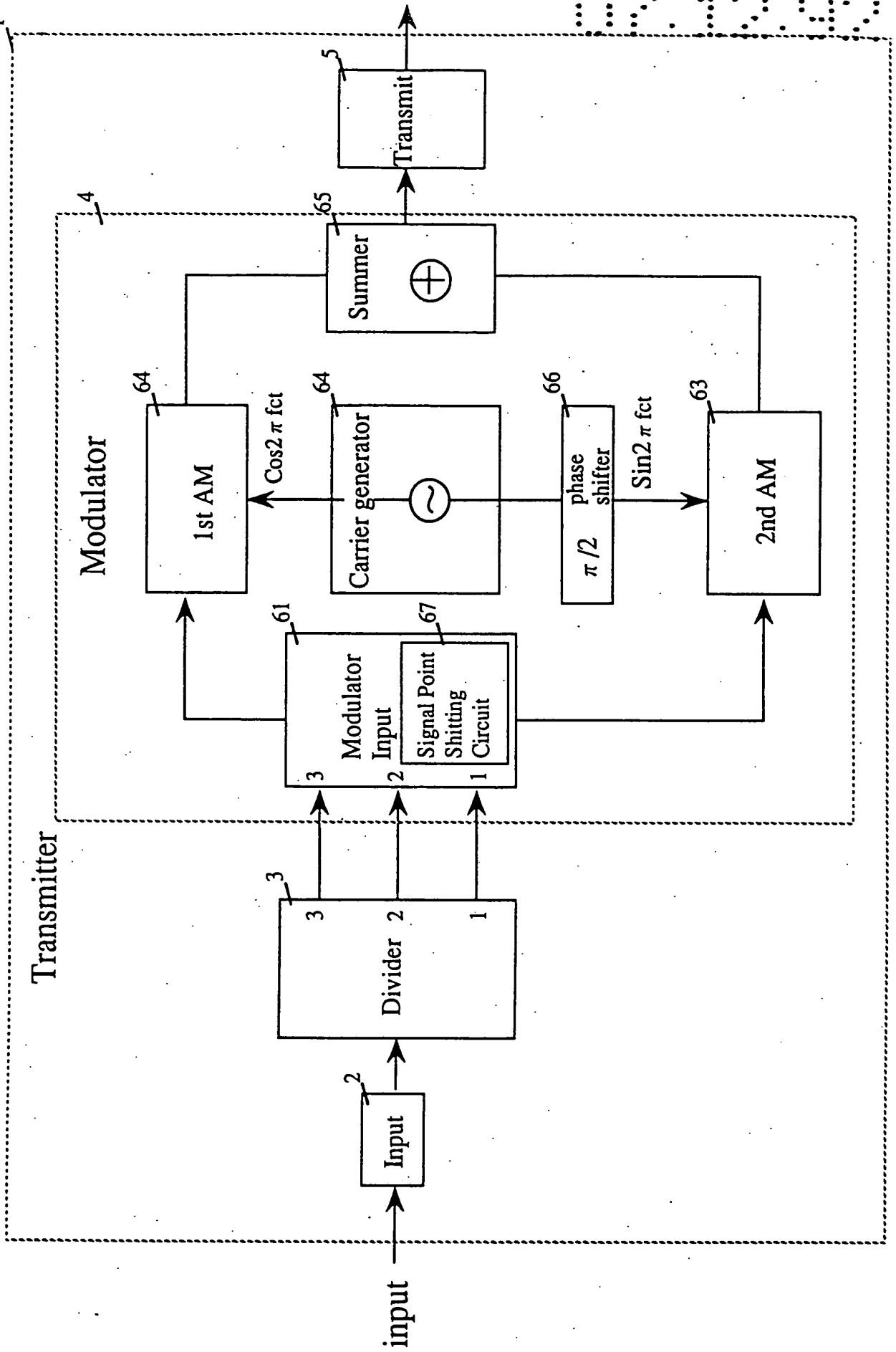
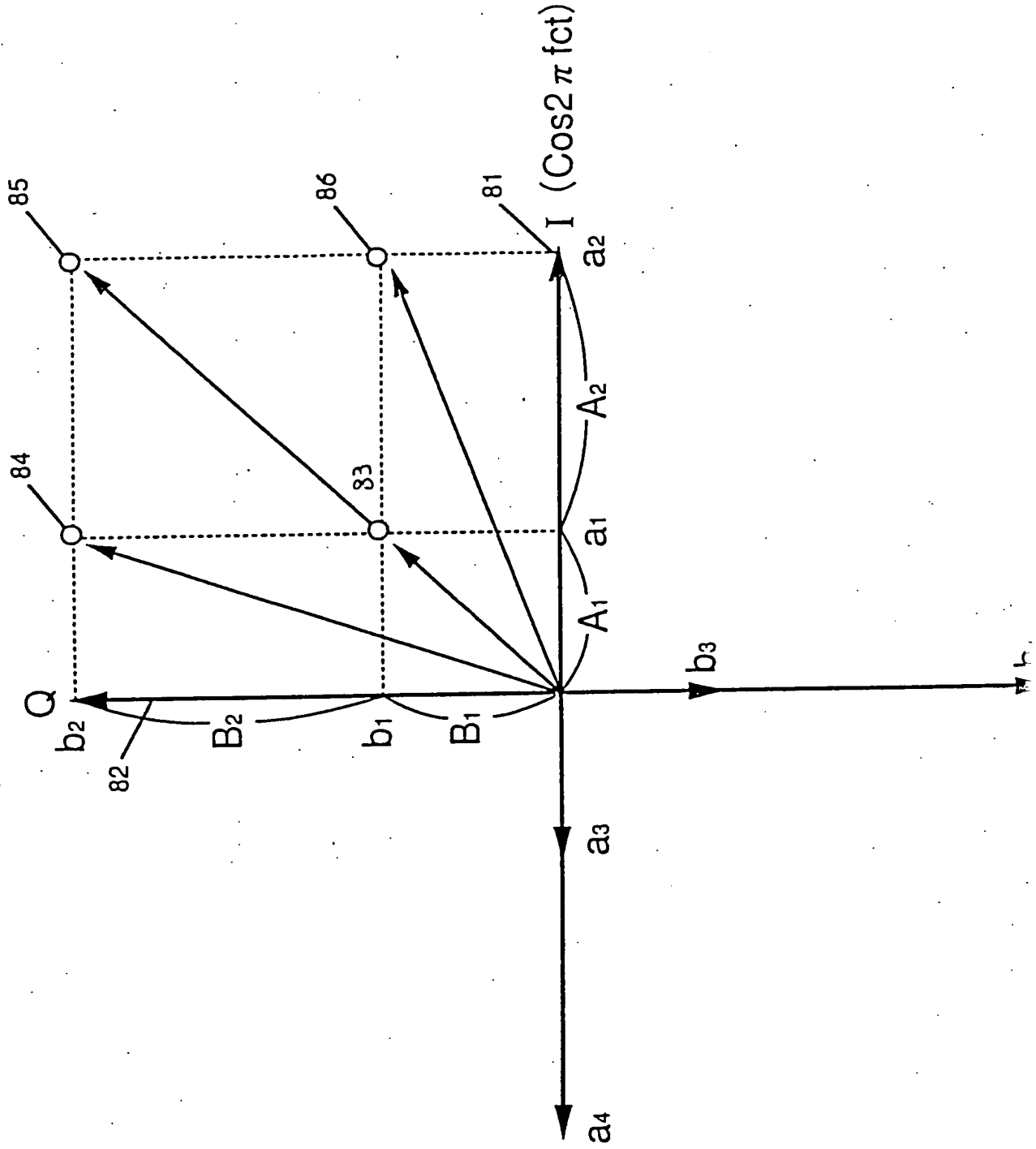


FIG. 3 $(\sin^2 \pi fct)$ 

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FIG. 4 ($\sin 2\pi \text{ fct}$)

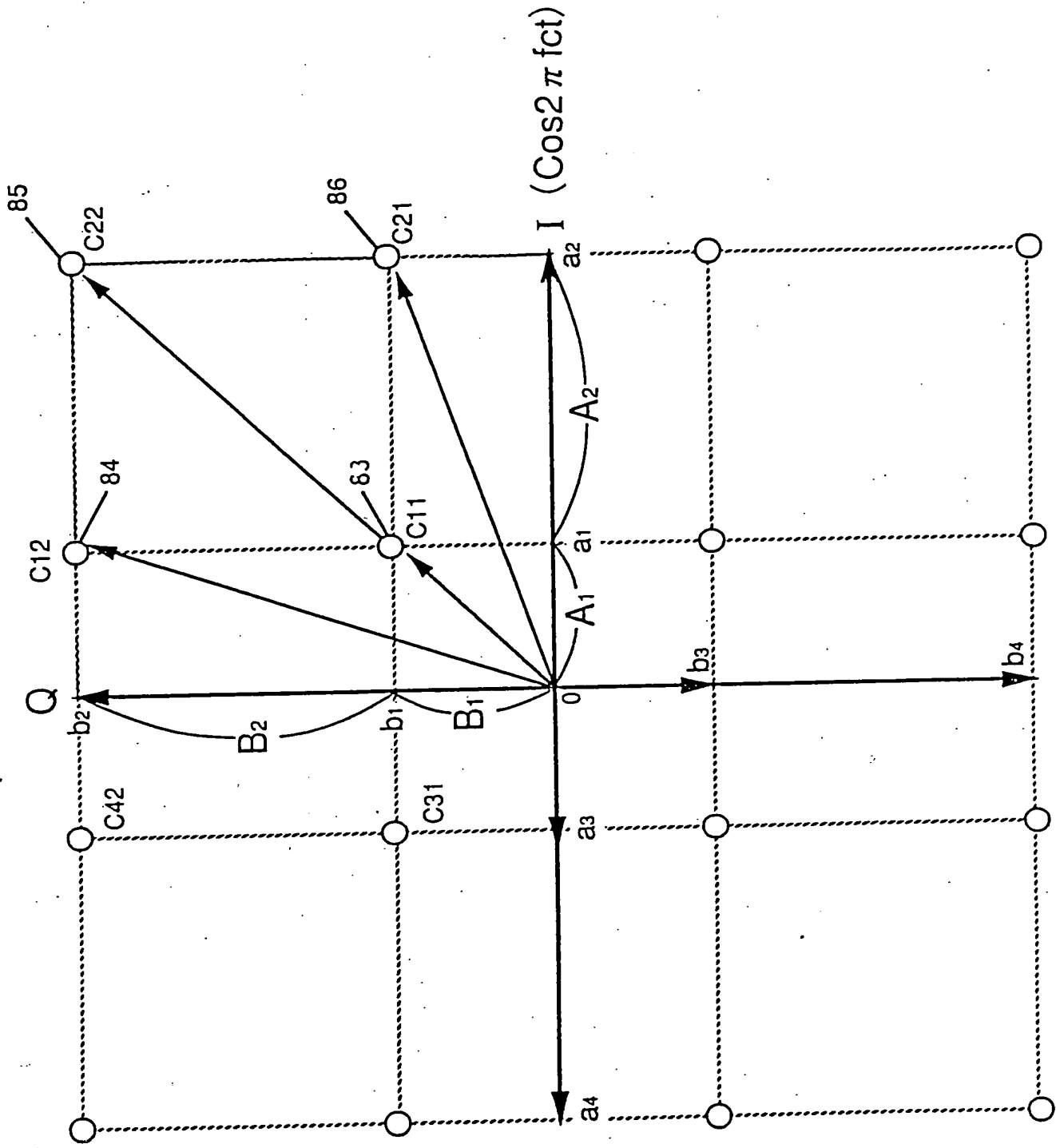
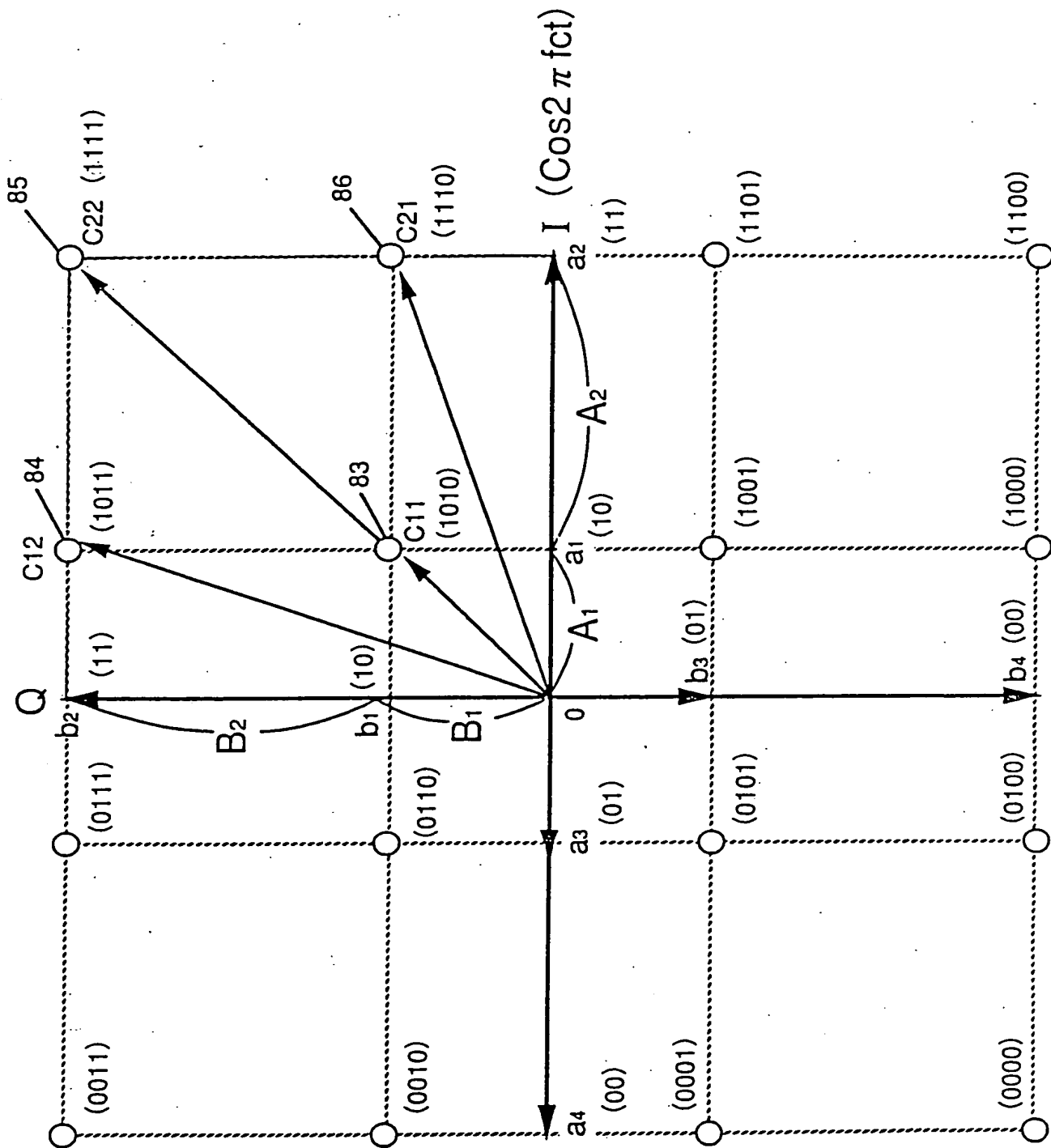
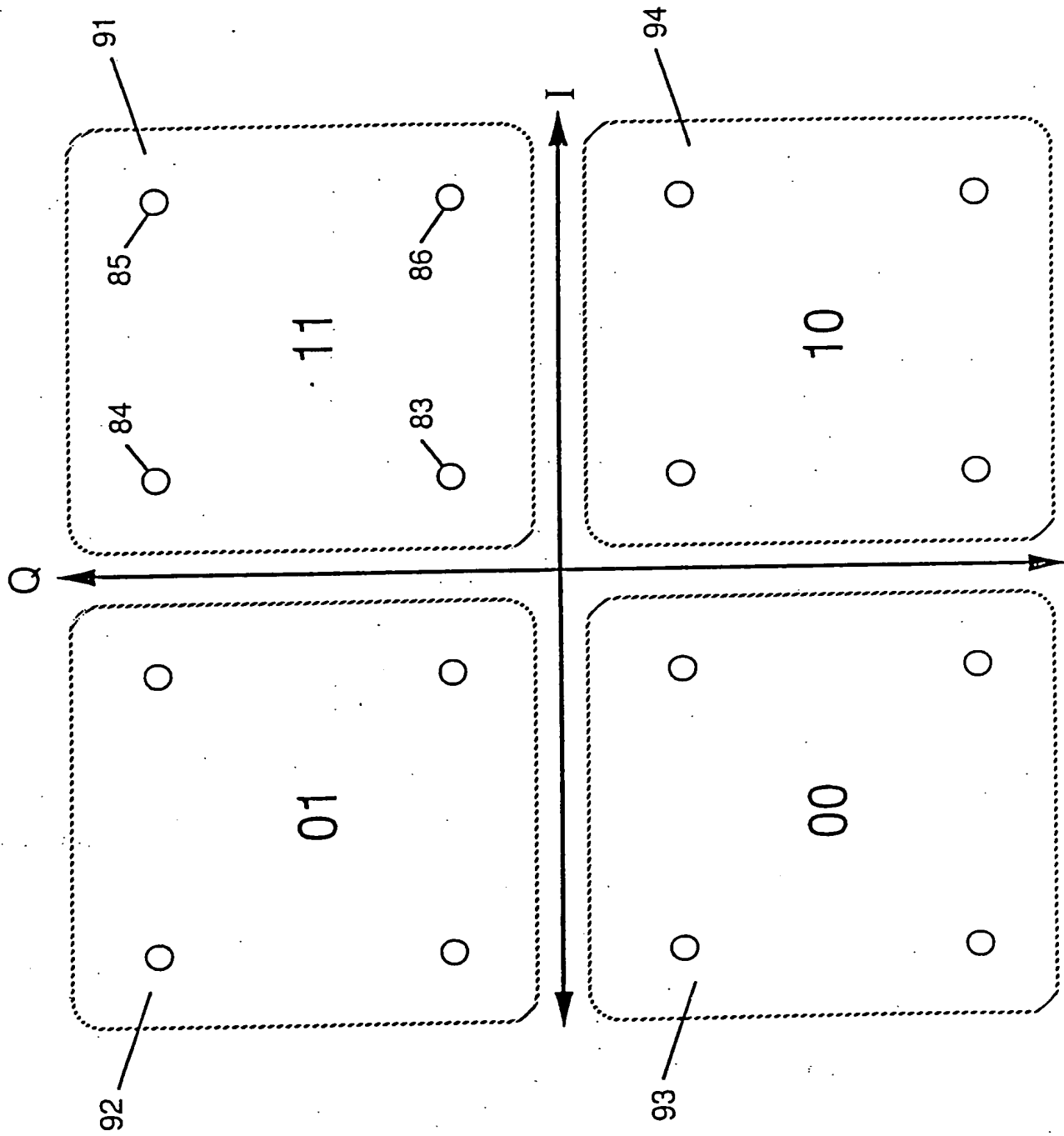


FIG. 5 ($\sin 2\pi \text{ fct}$)

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FIG. 6



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FIG. 7

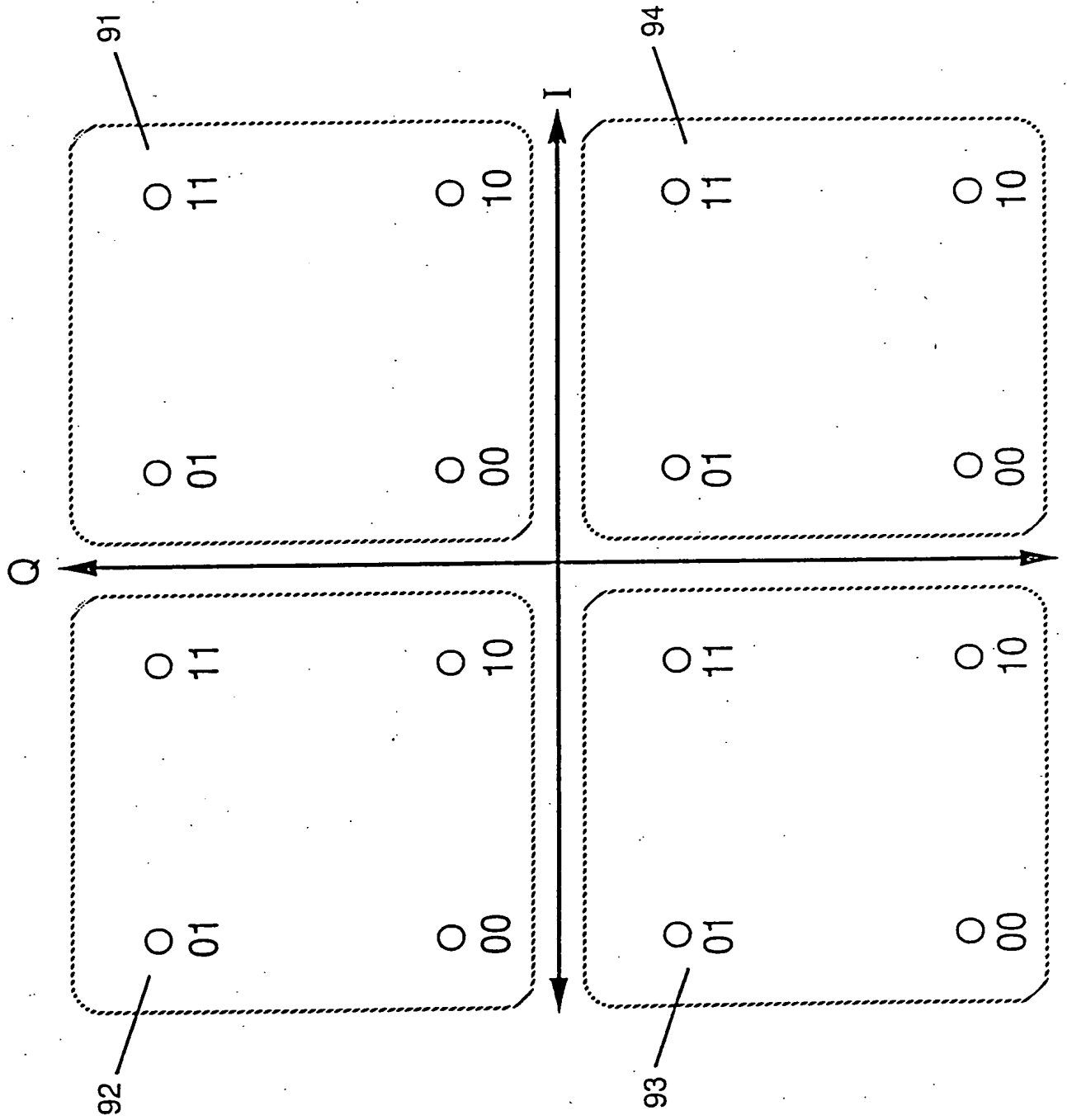
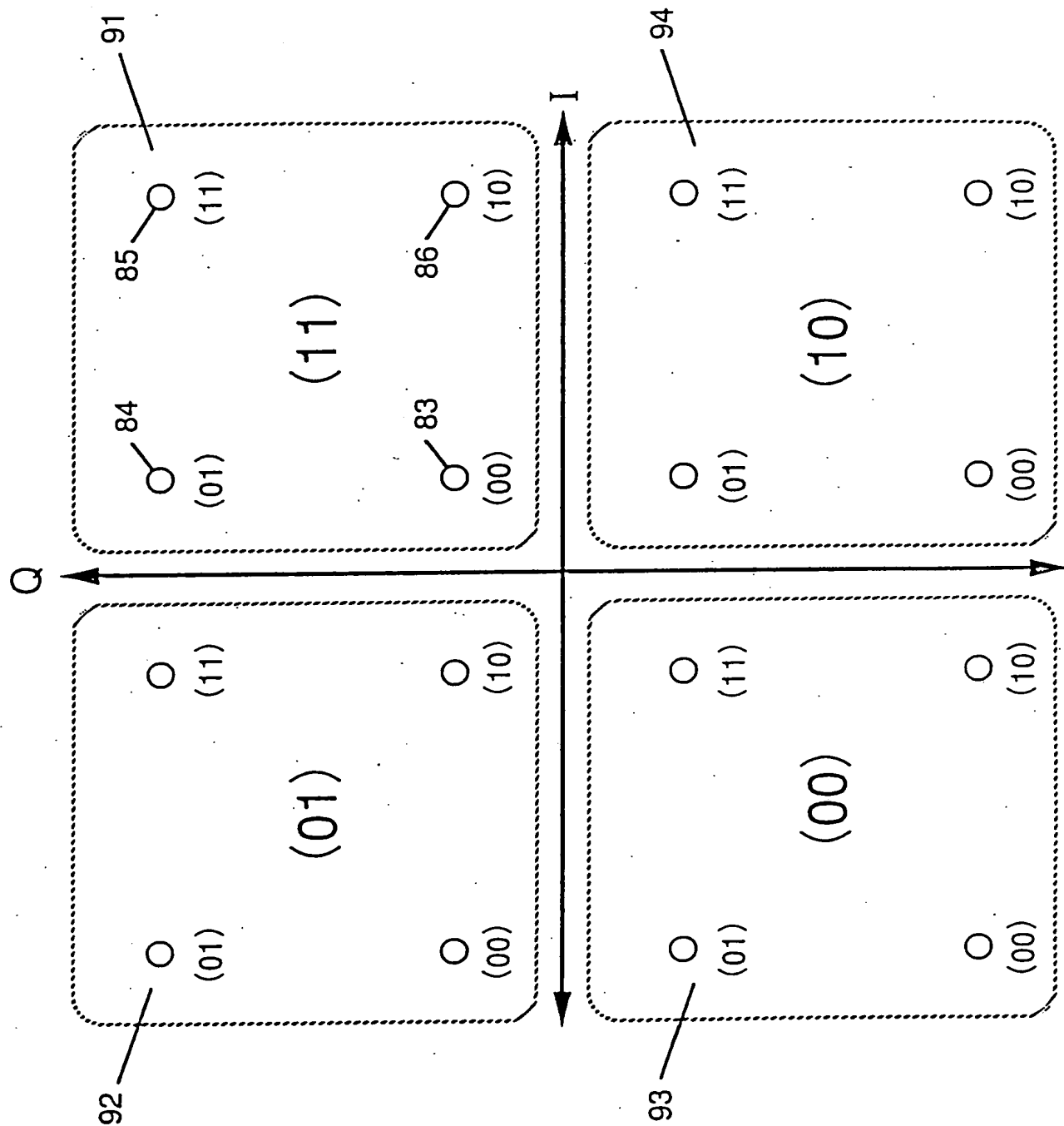


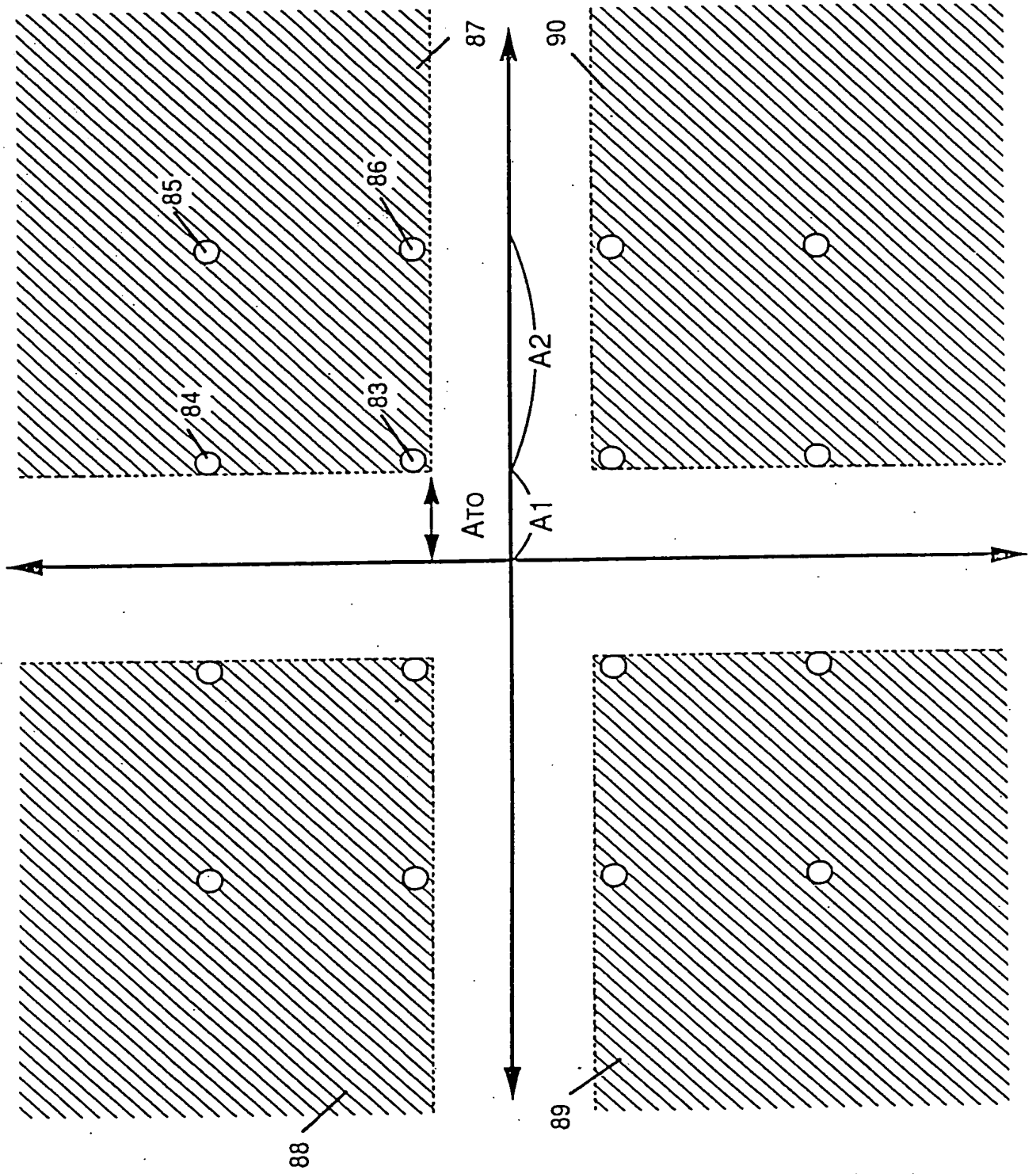
FIG. 8



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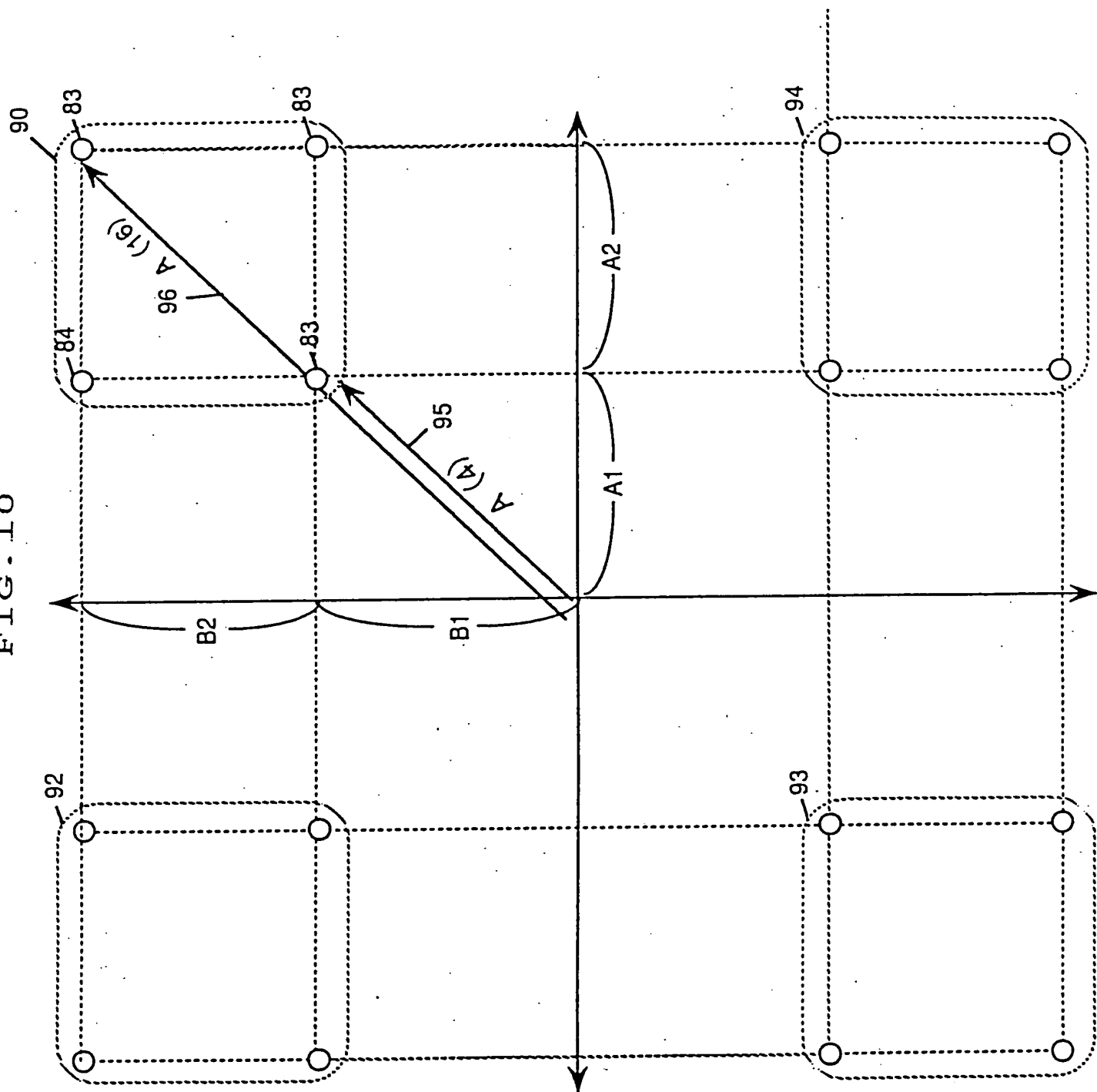
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FIG. 9



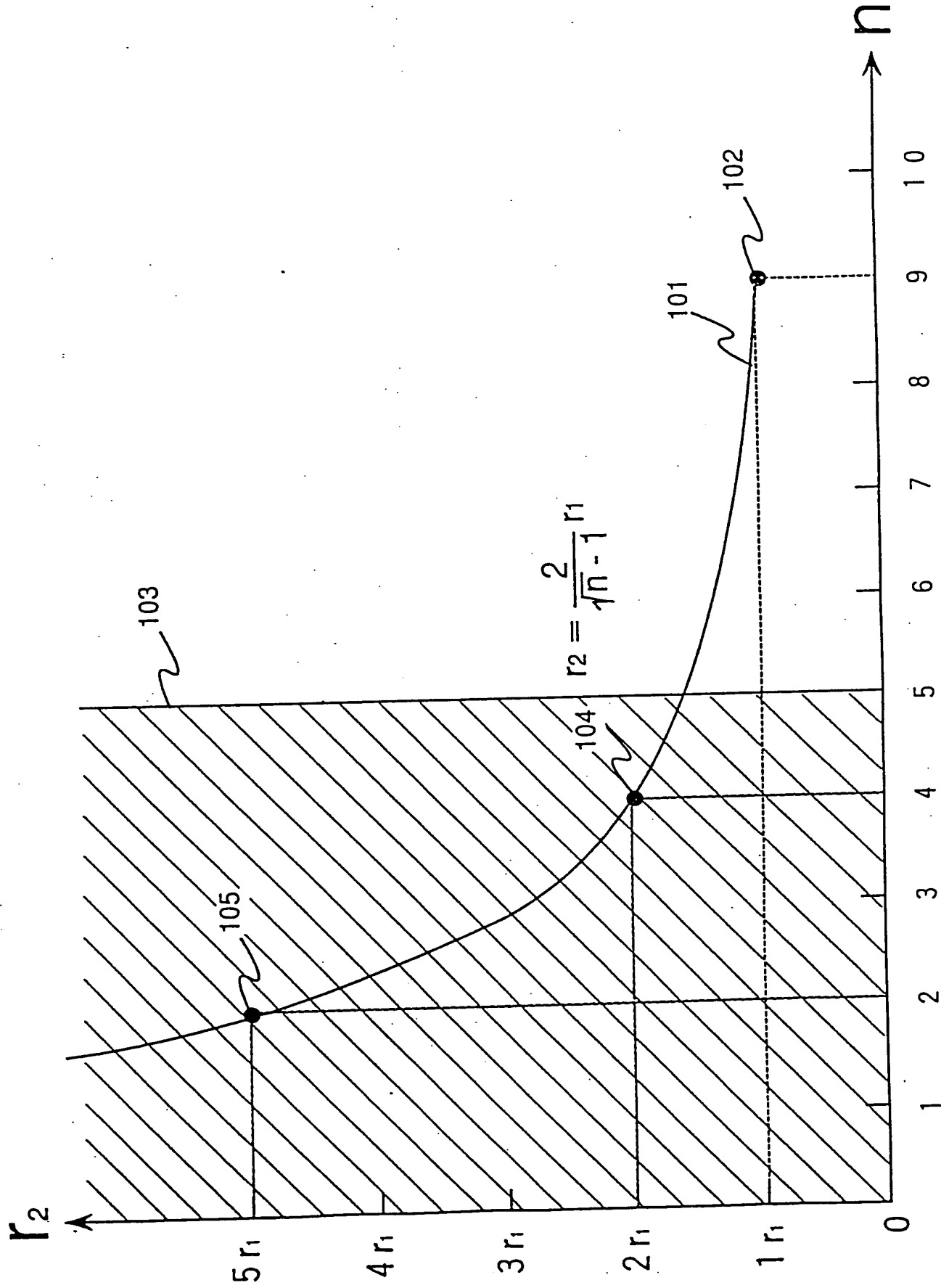
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FIG. 10



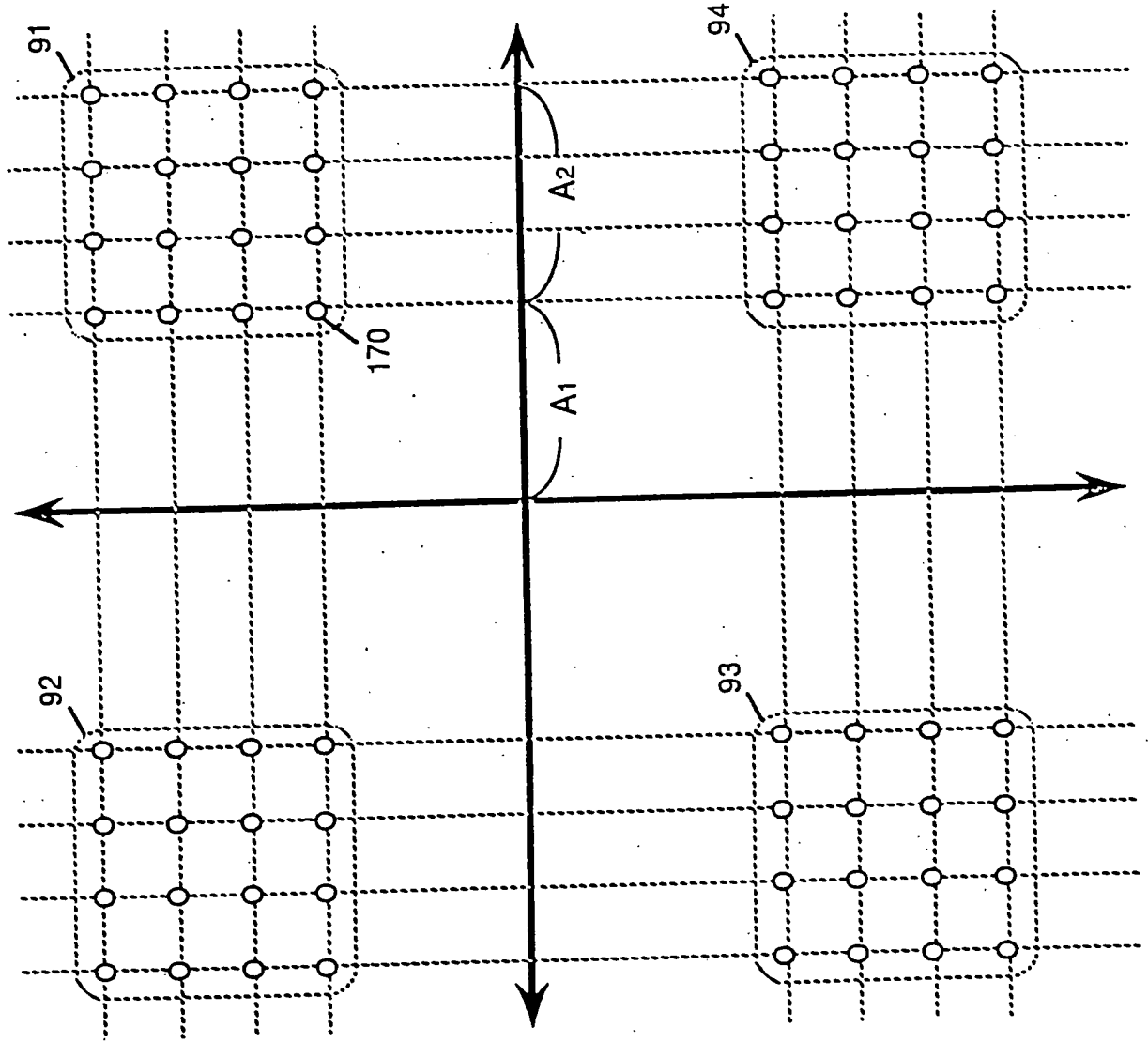
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FIG. 11



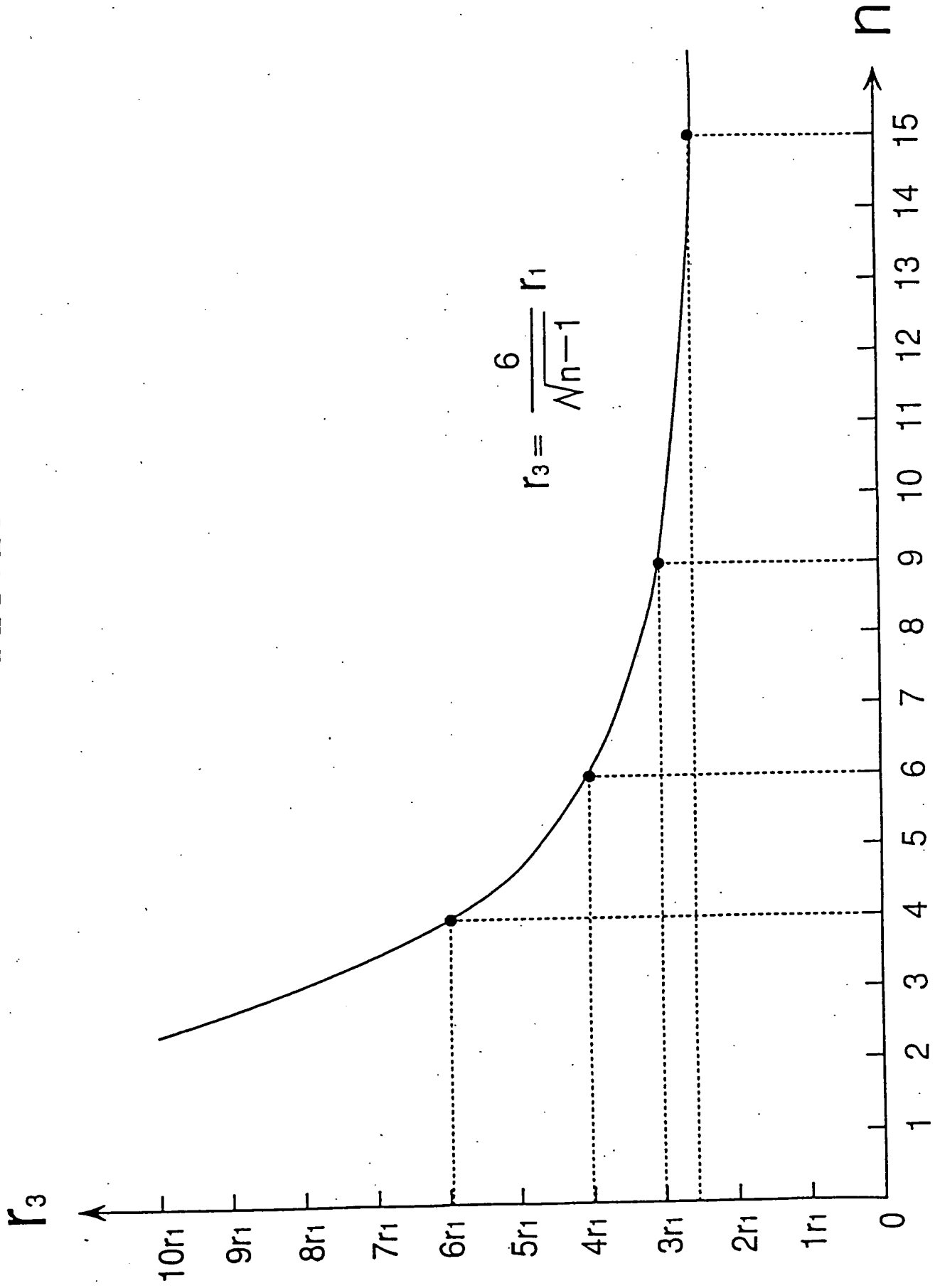
07.12.92

FIG. 12



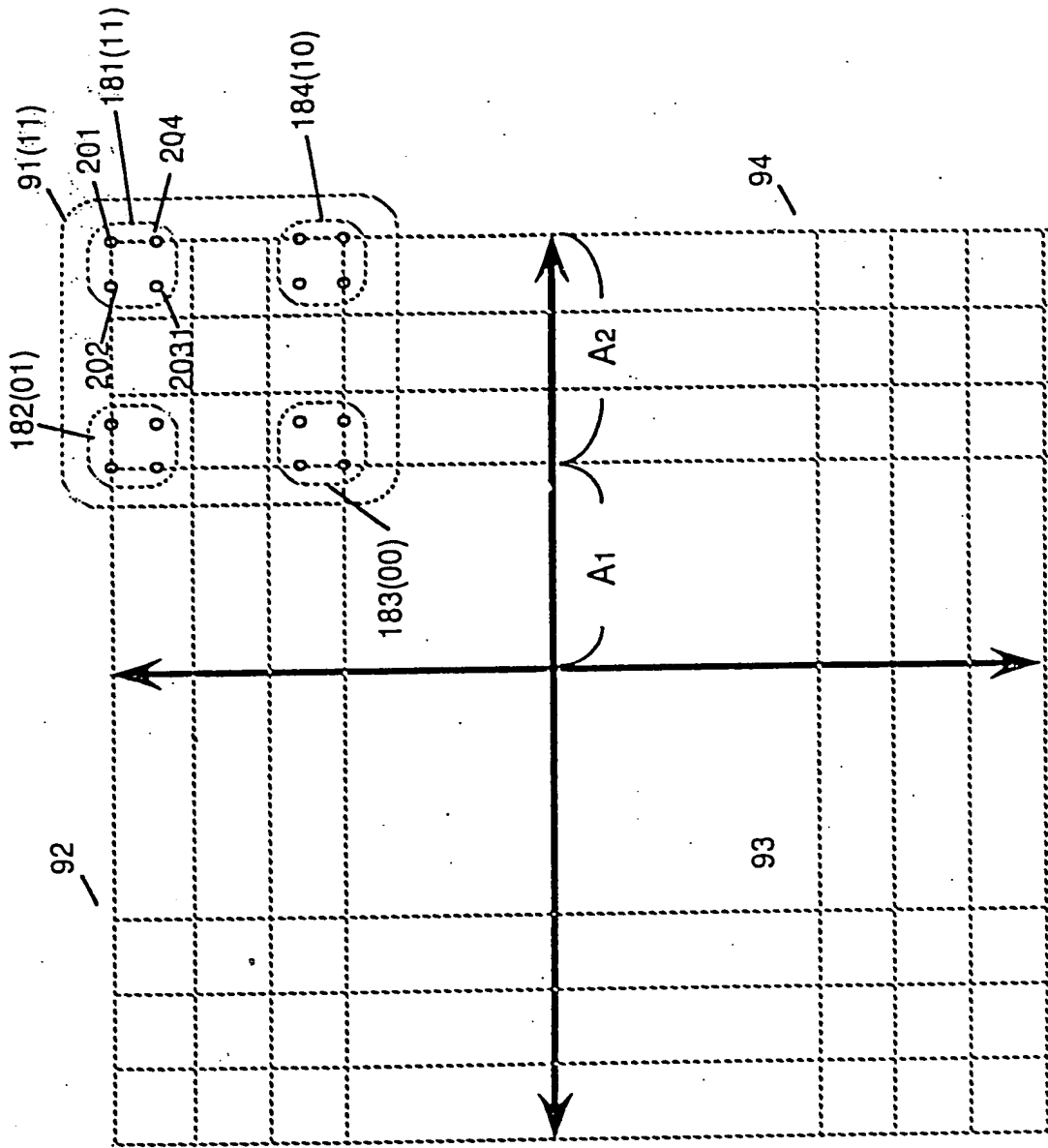
07.12.90

FIG. 13



07.12.92

FIG. 14



07.12.93

FIG. 15

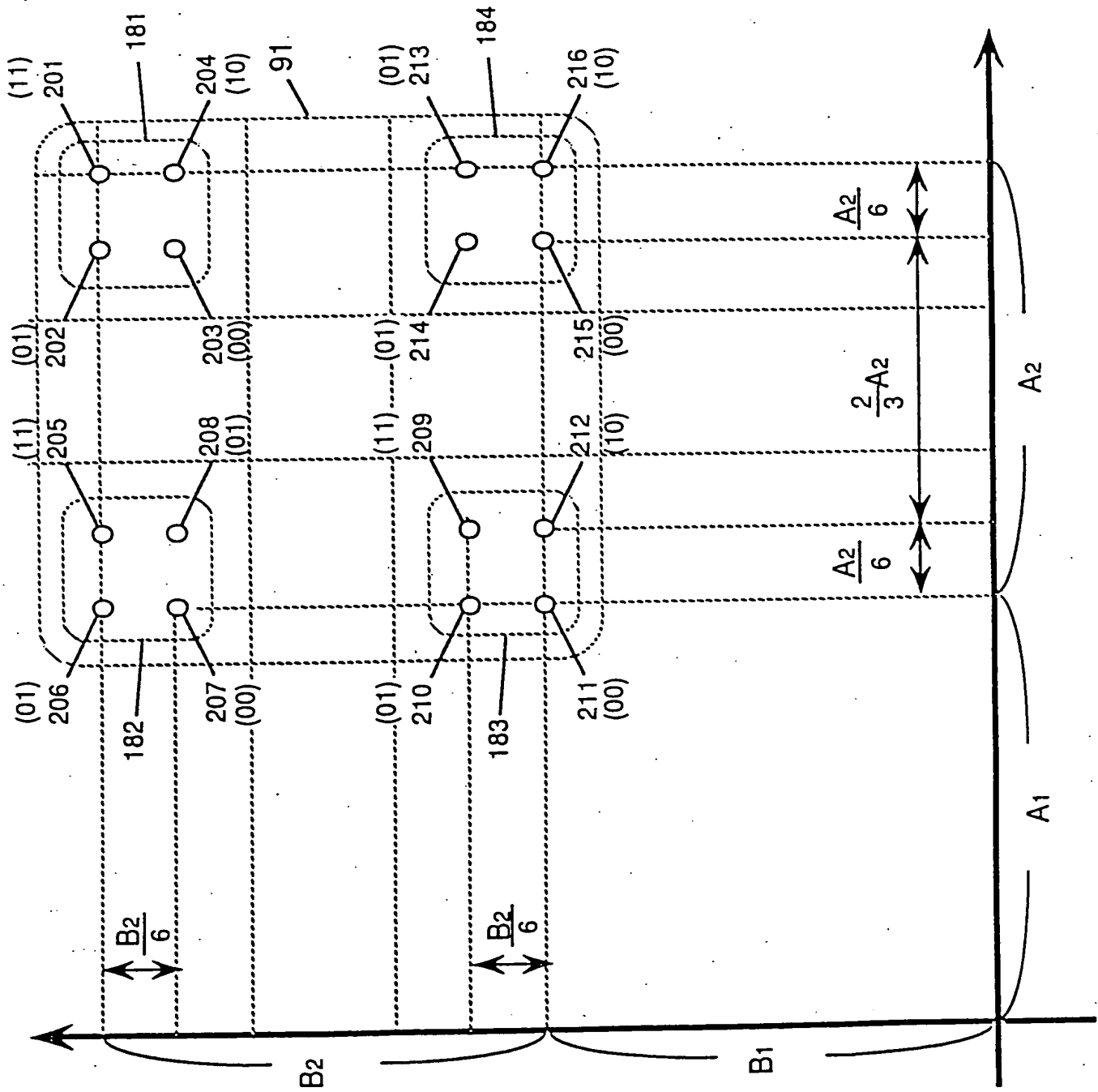


FIG. 16

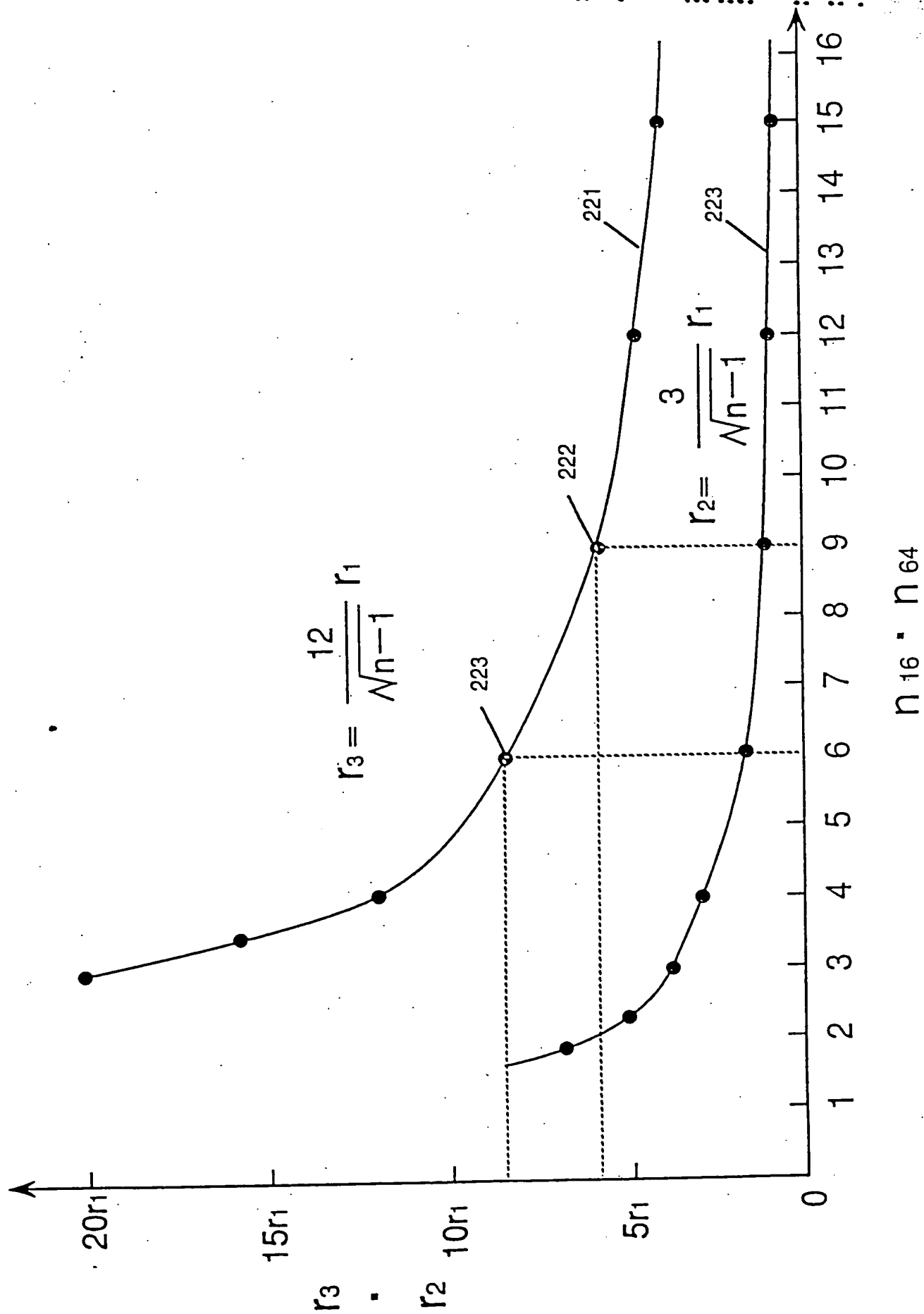


FIG. 17

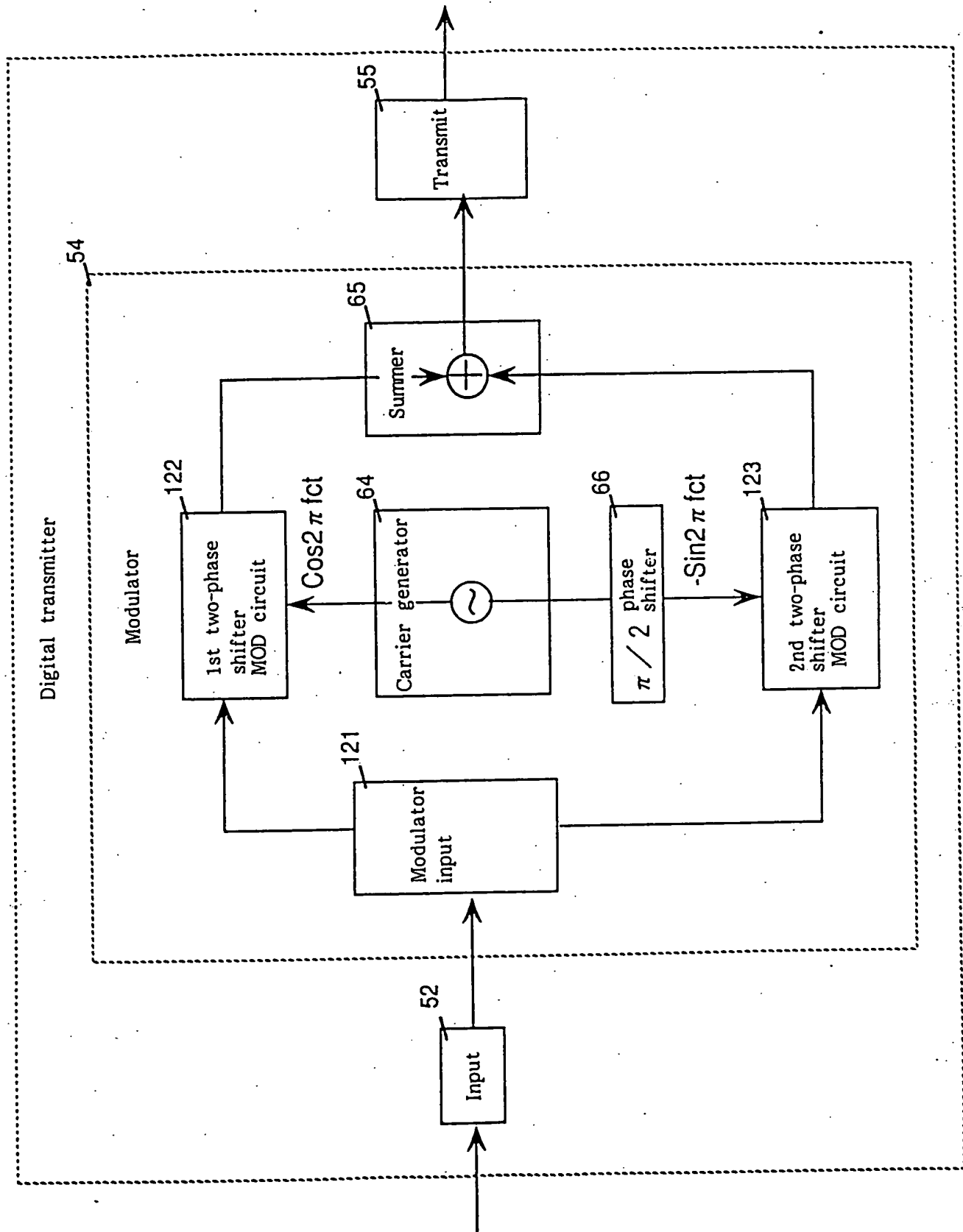


Fig.18

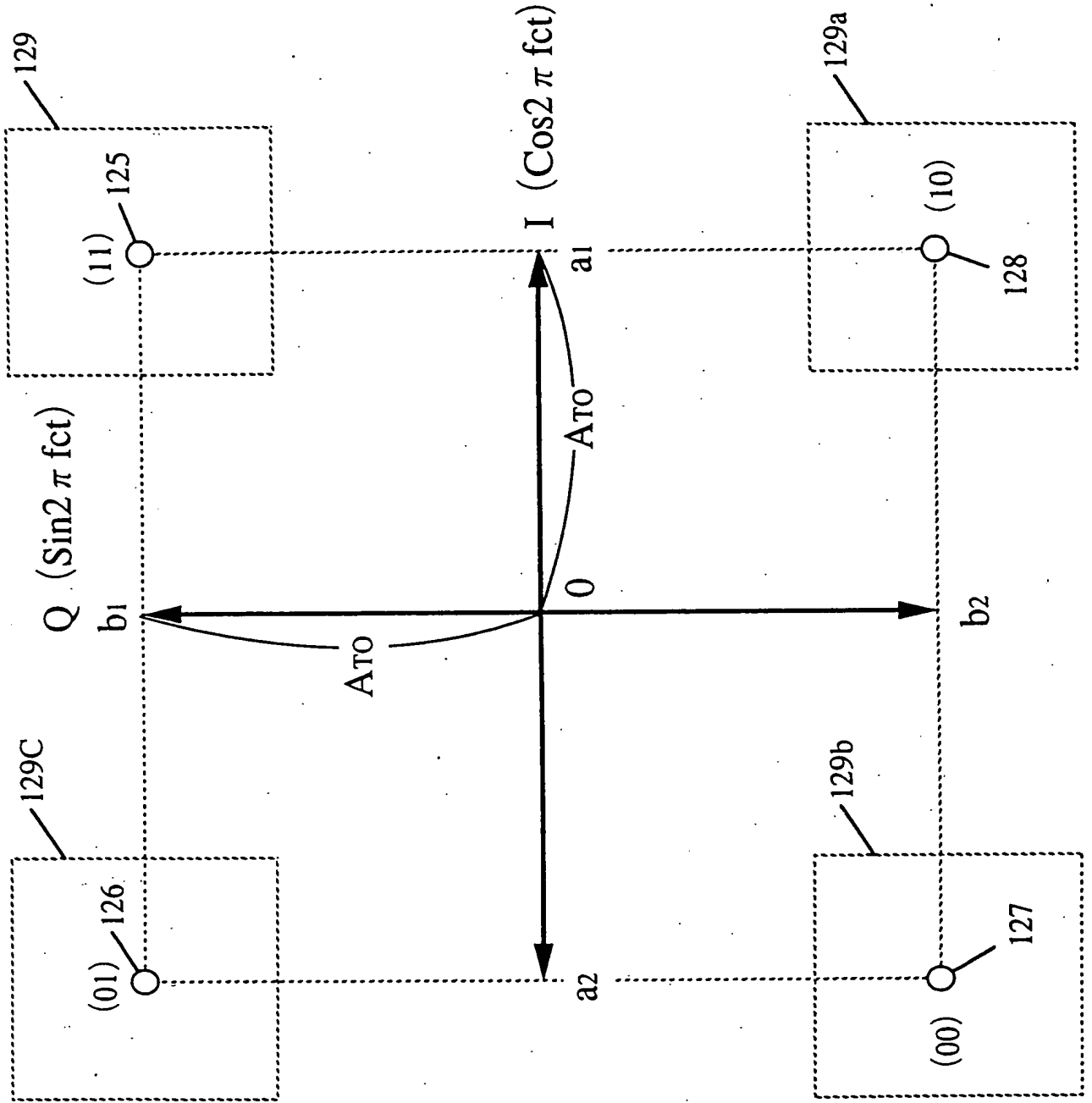


FIG.19

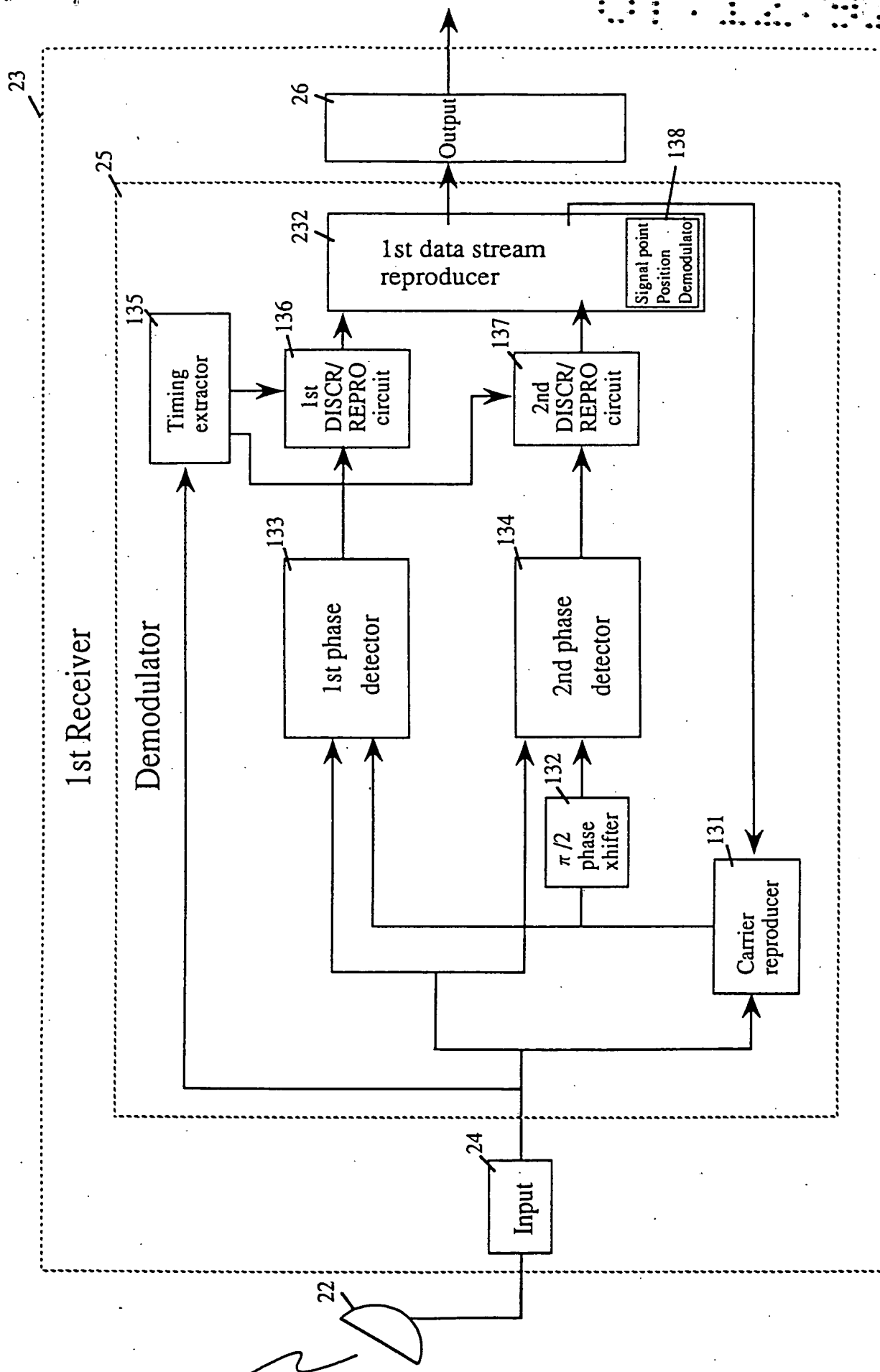


FIG. 20

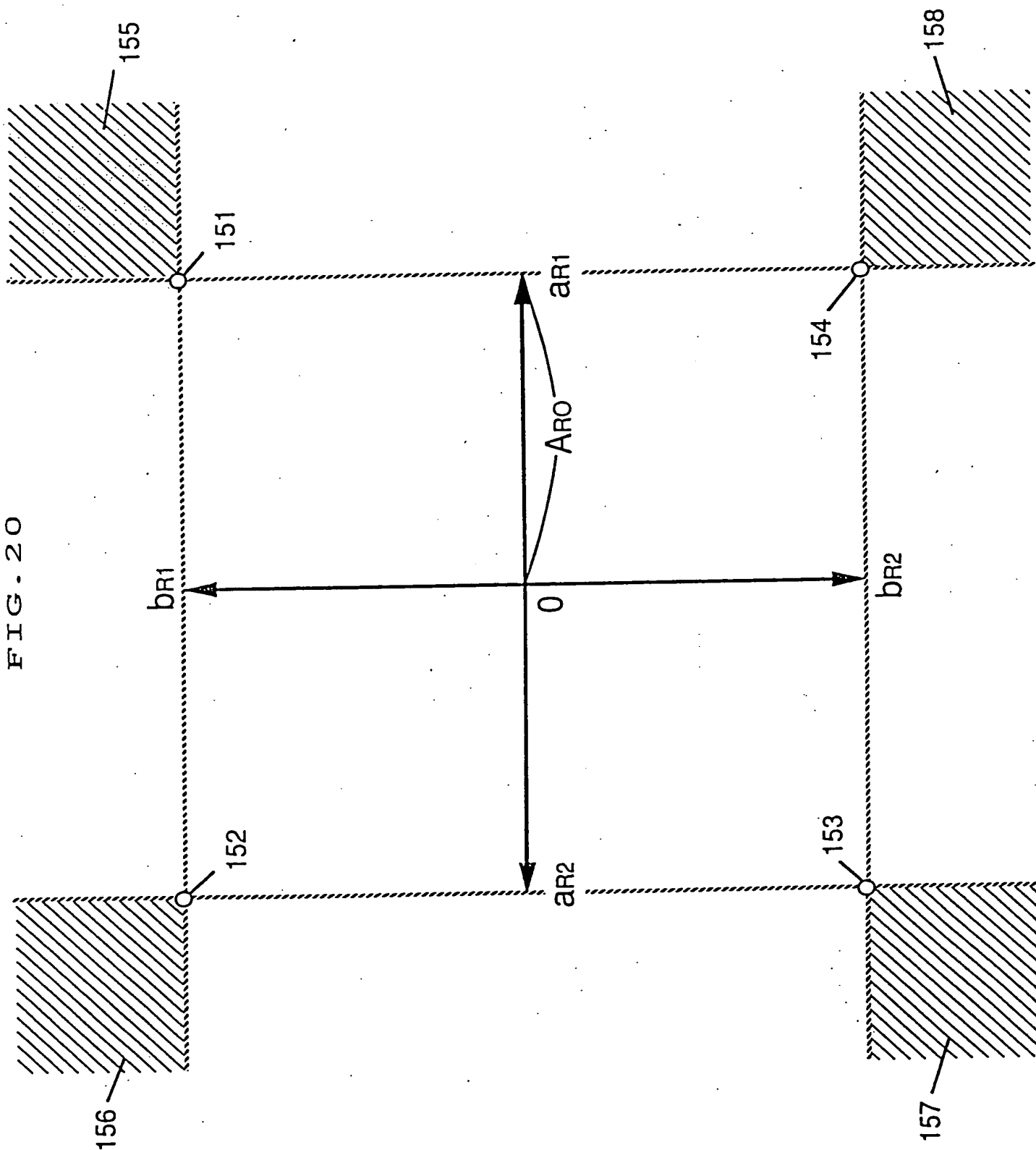
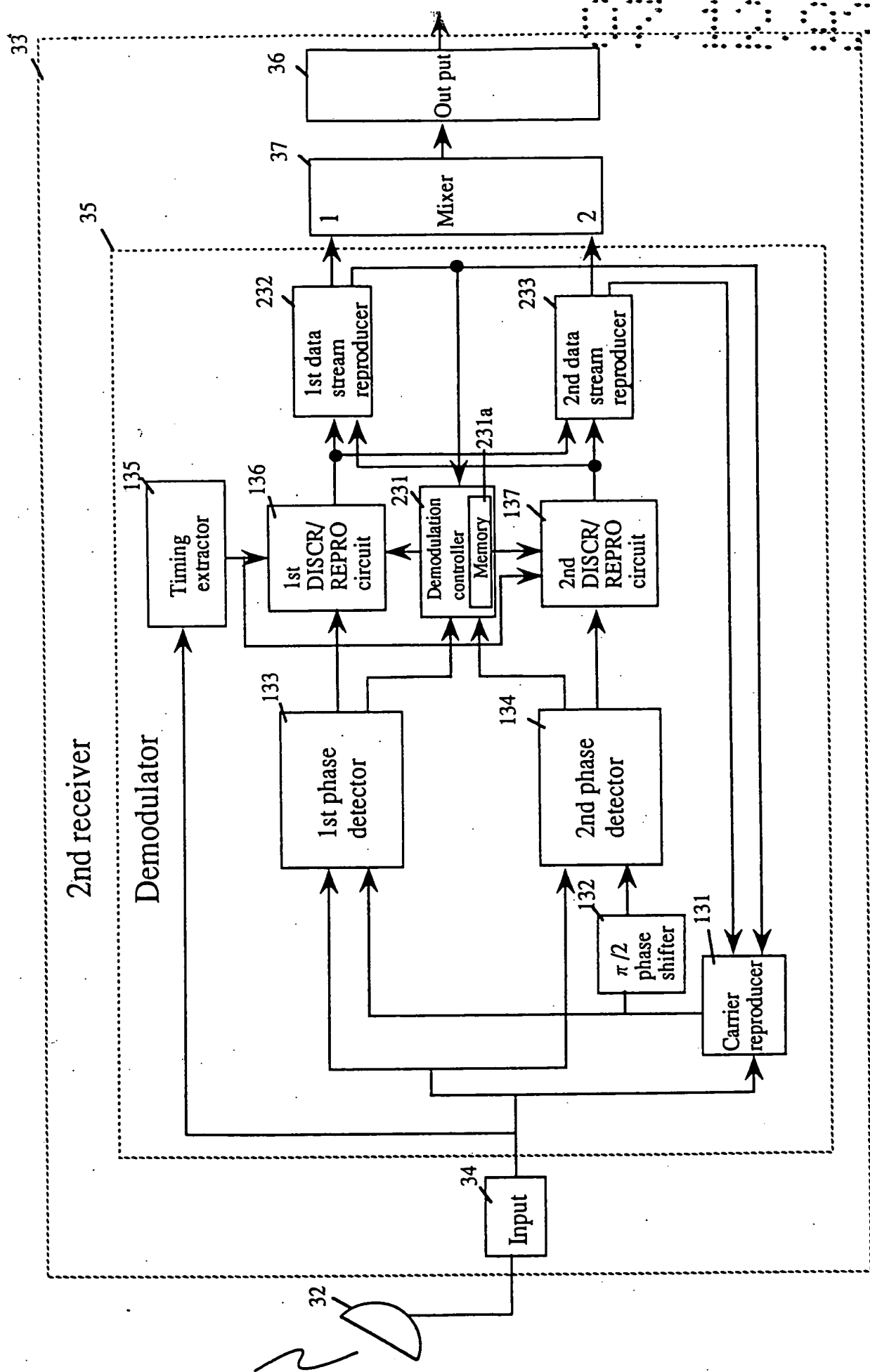
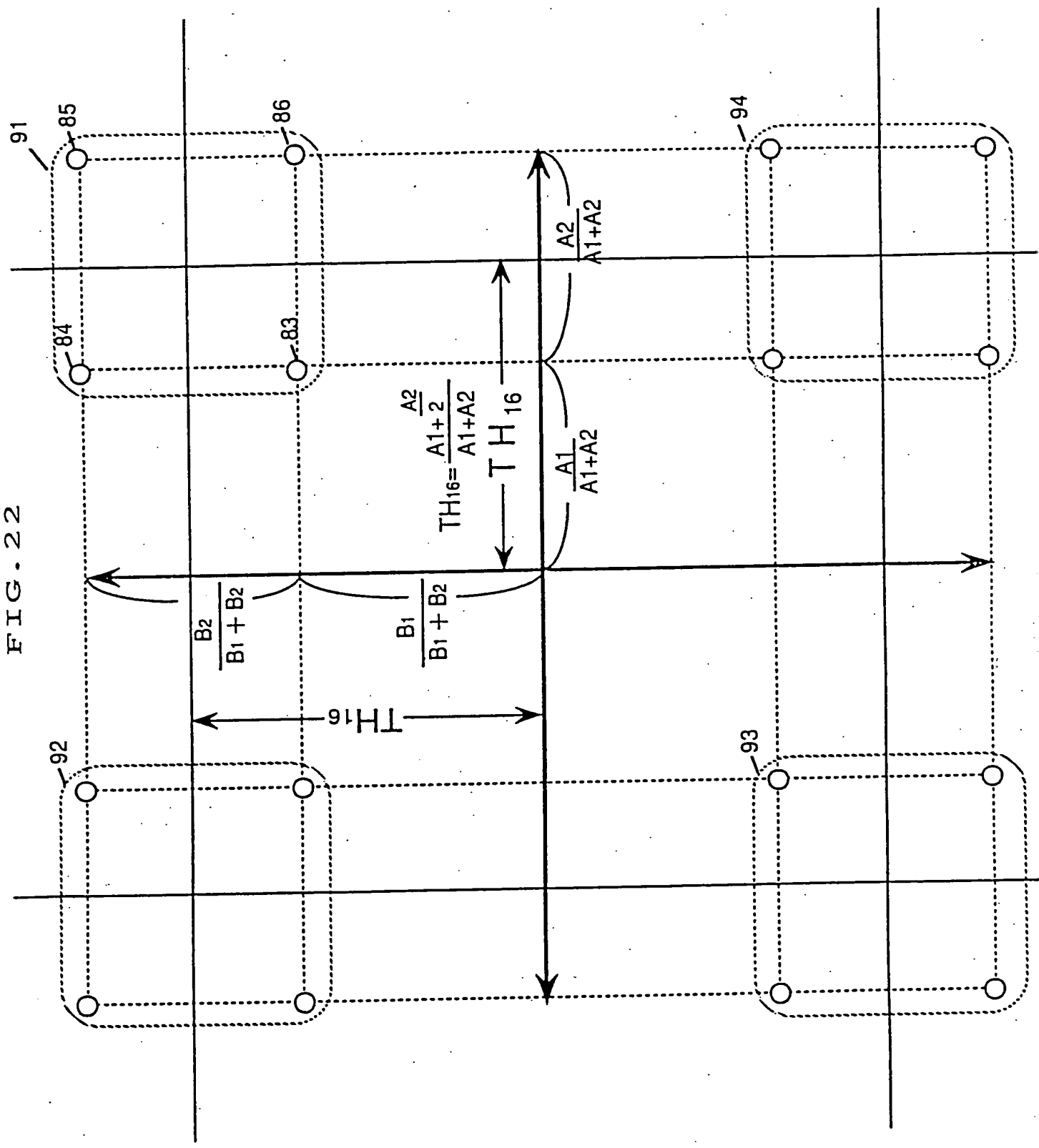


FIG.21



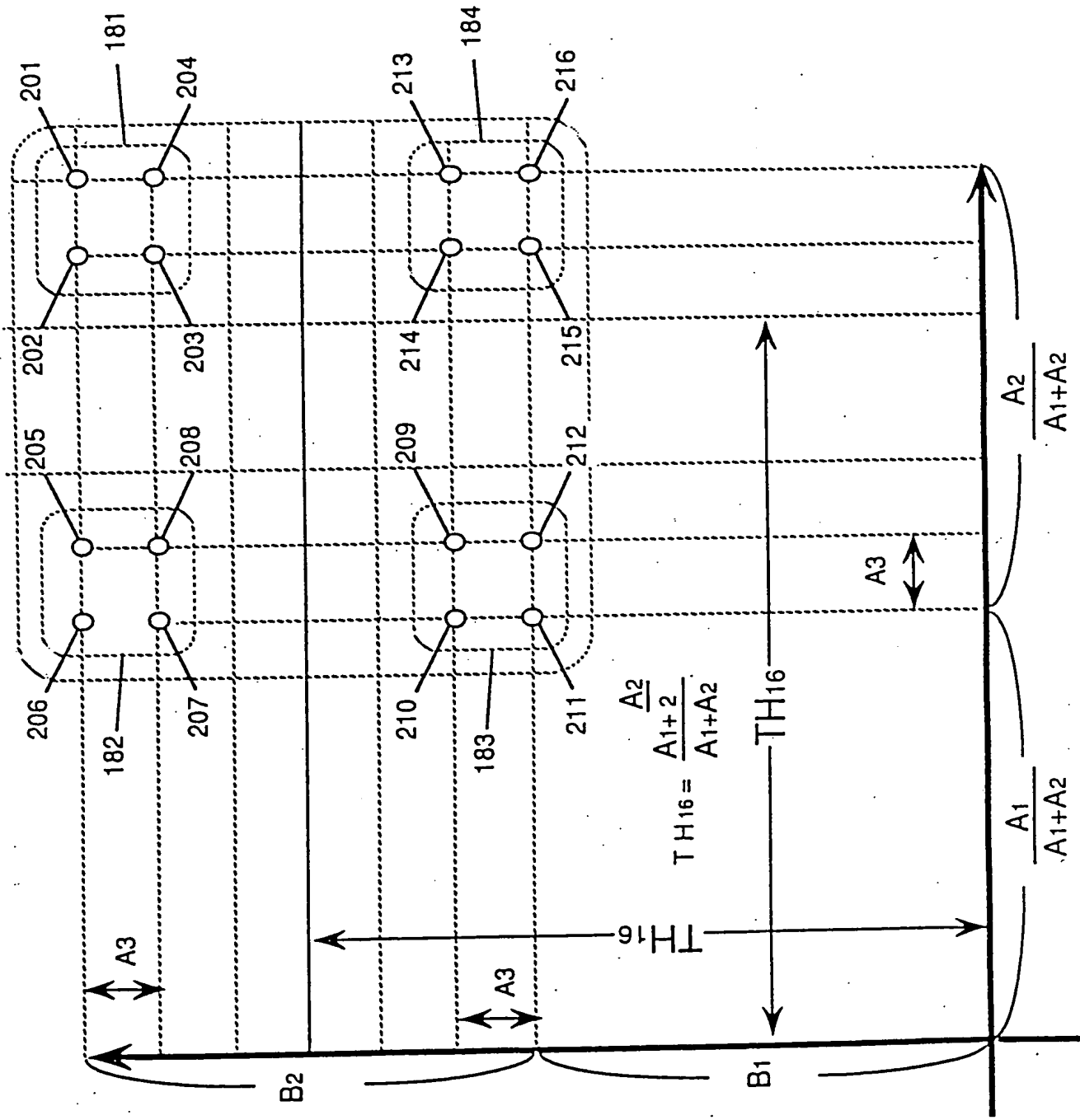
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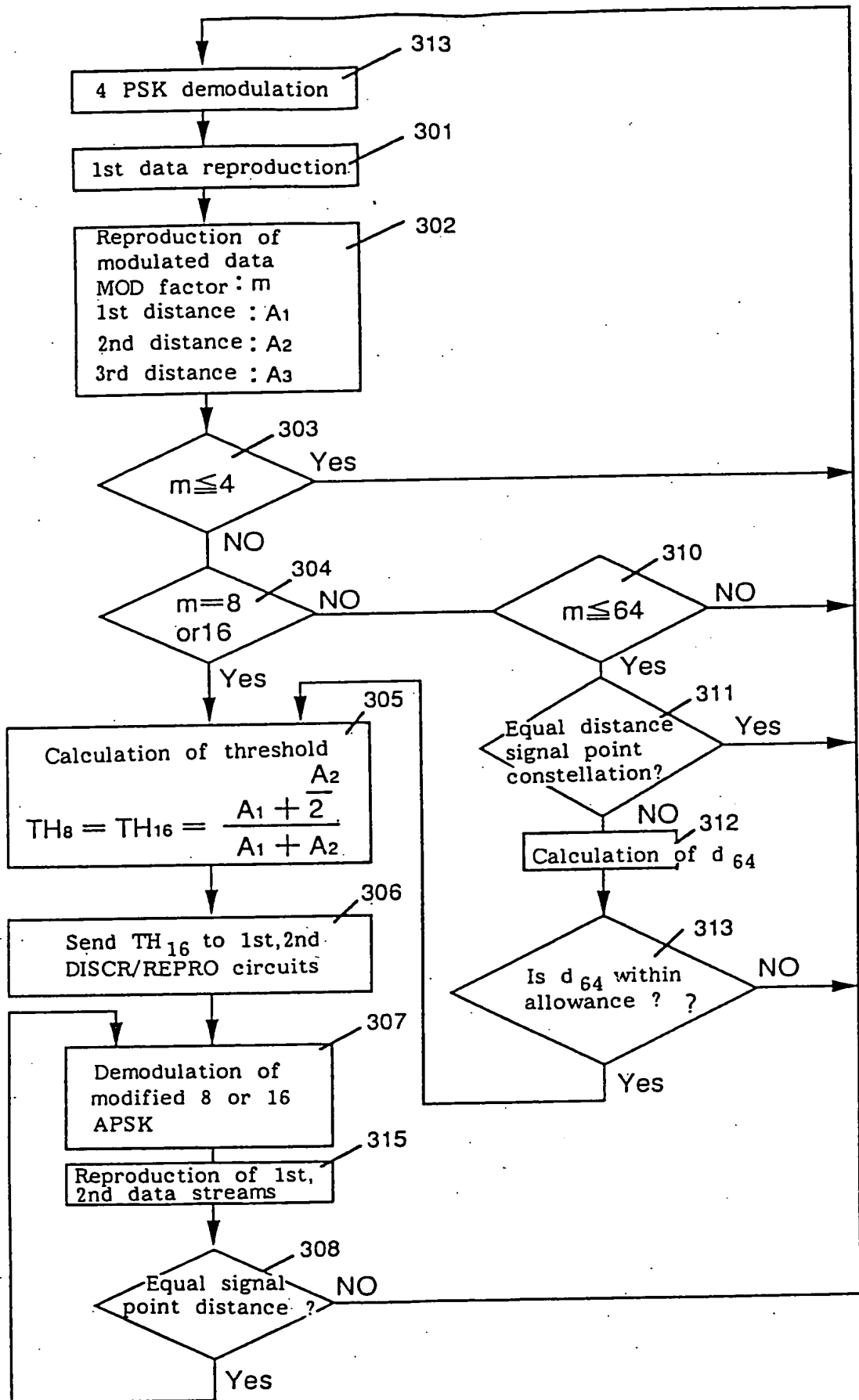
FIG. 22



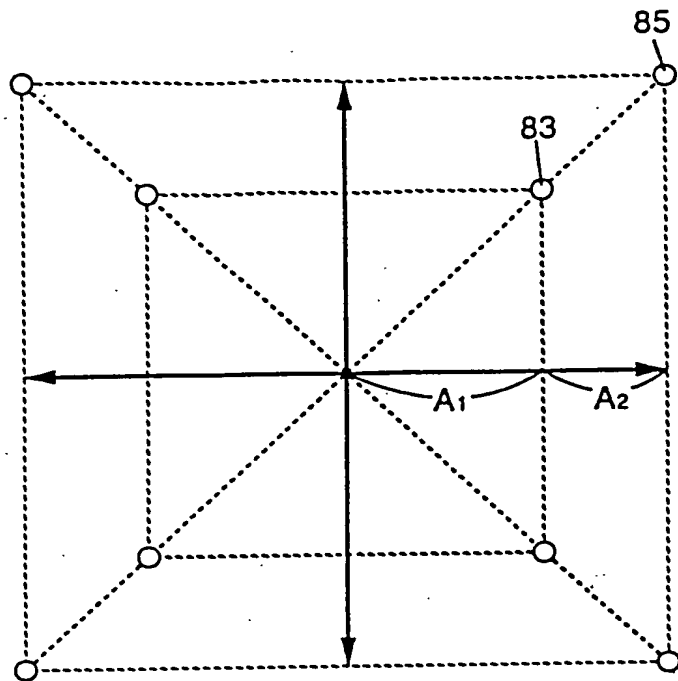
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FIG. 23





(a)



(b)

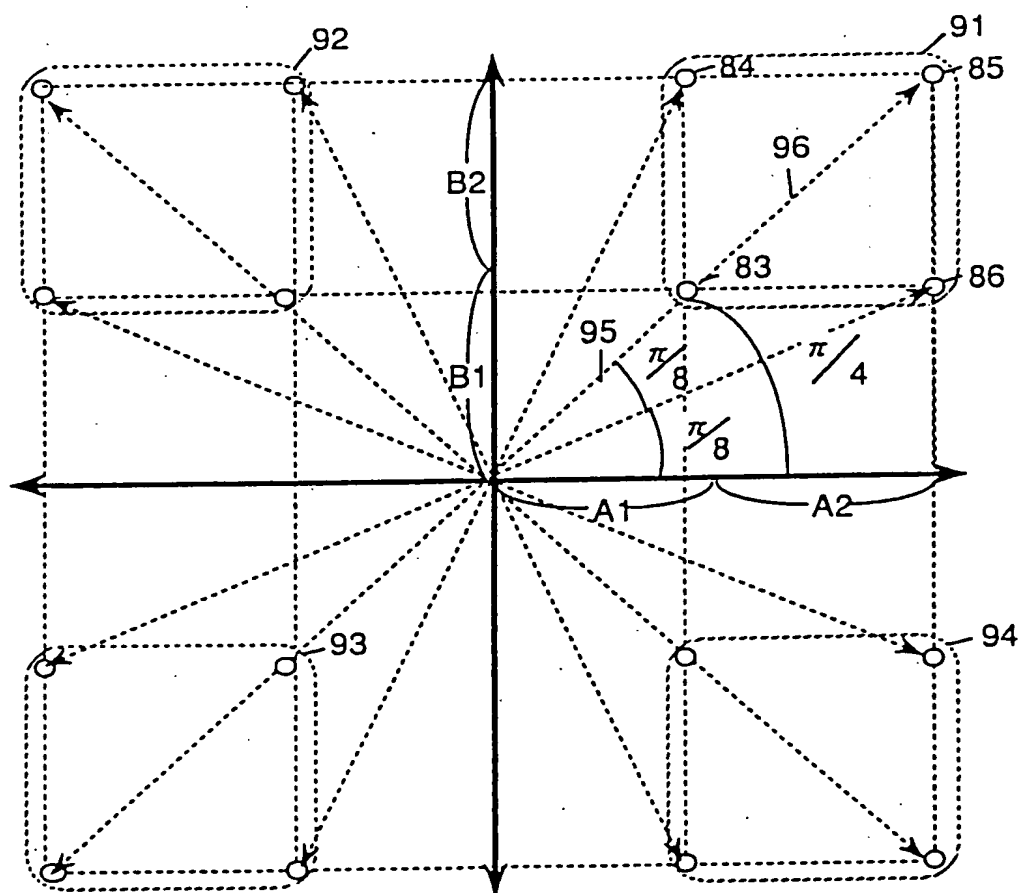


FIG.26

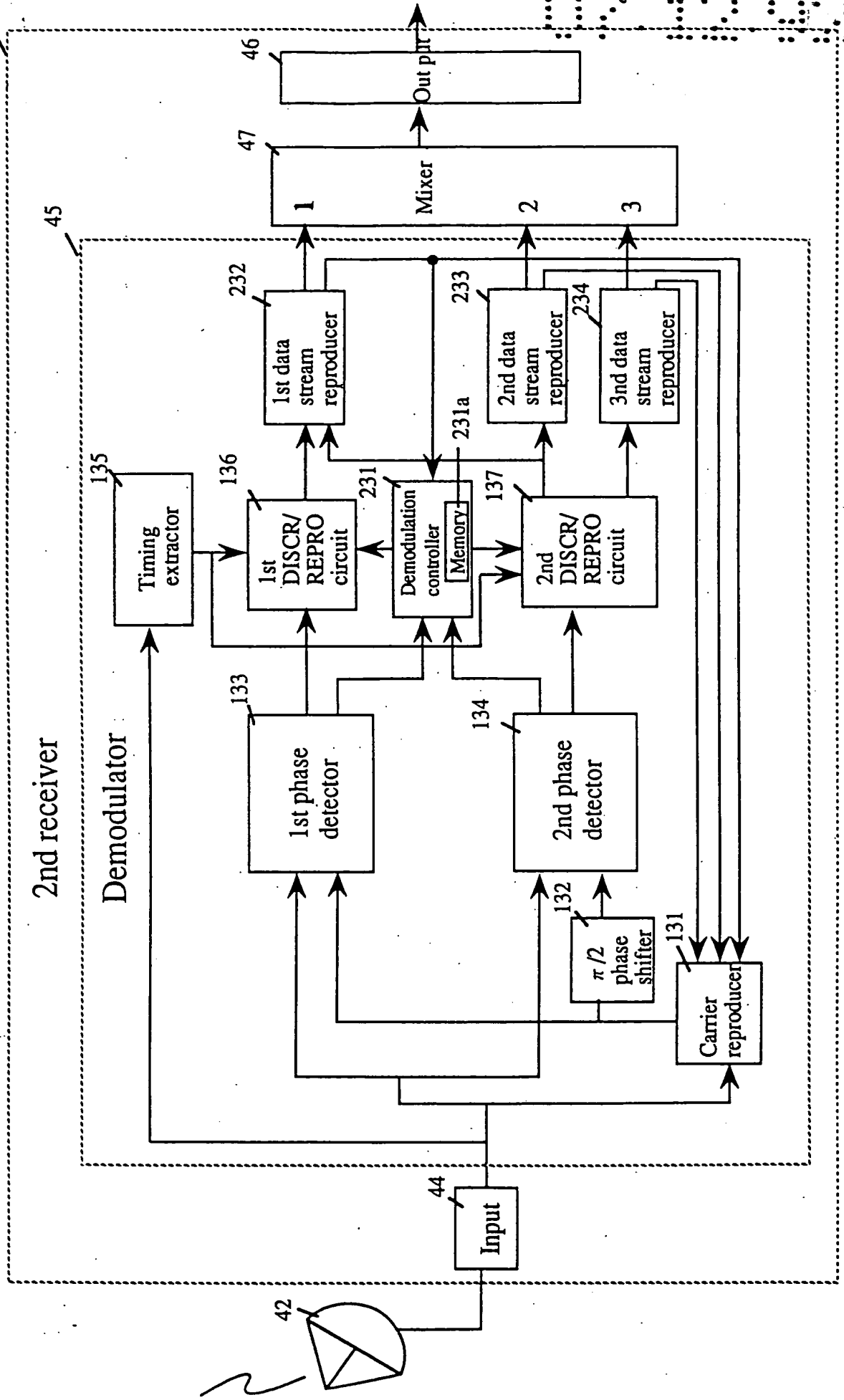
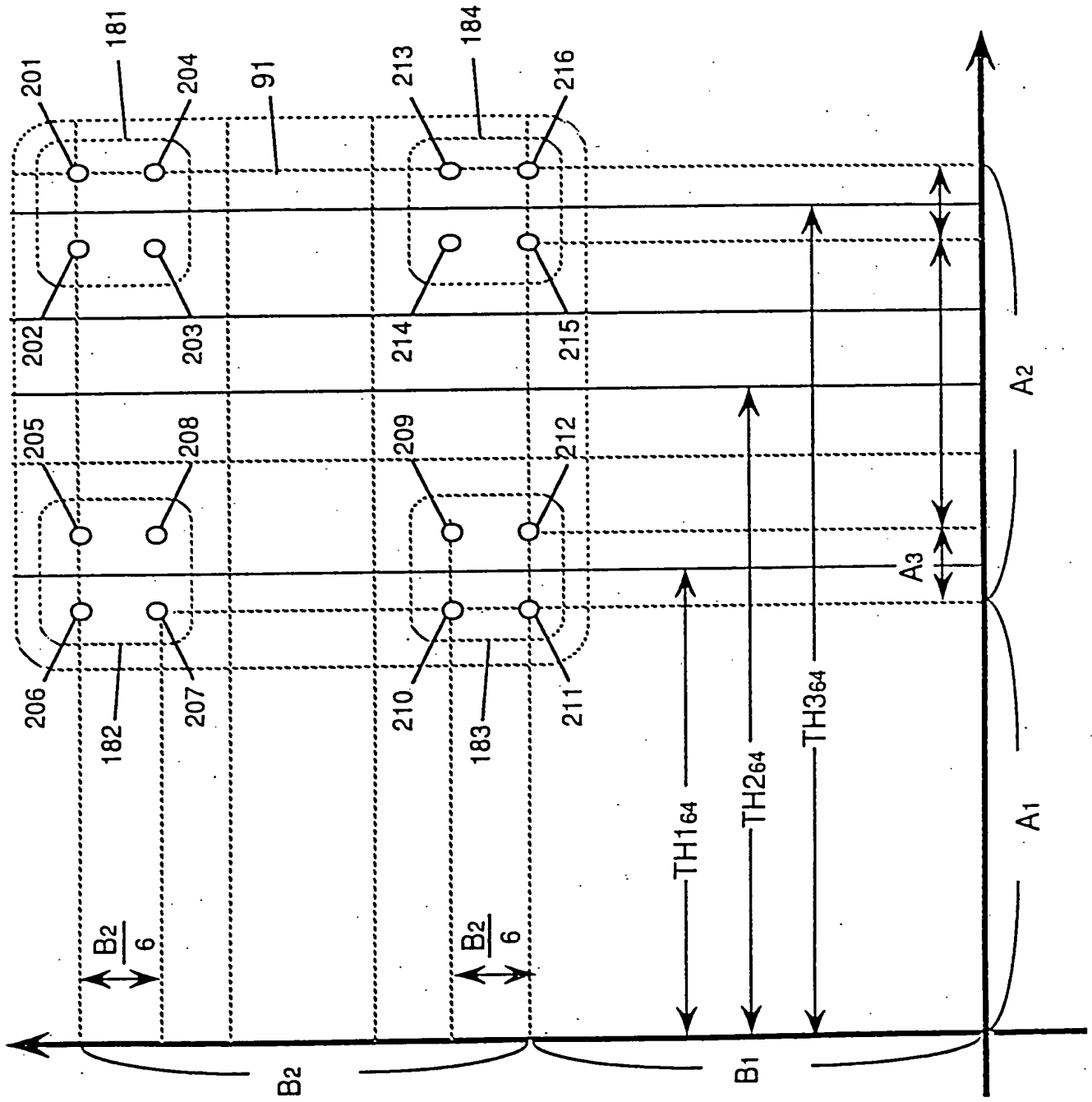


FIG. 27



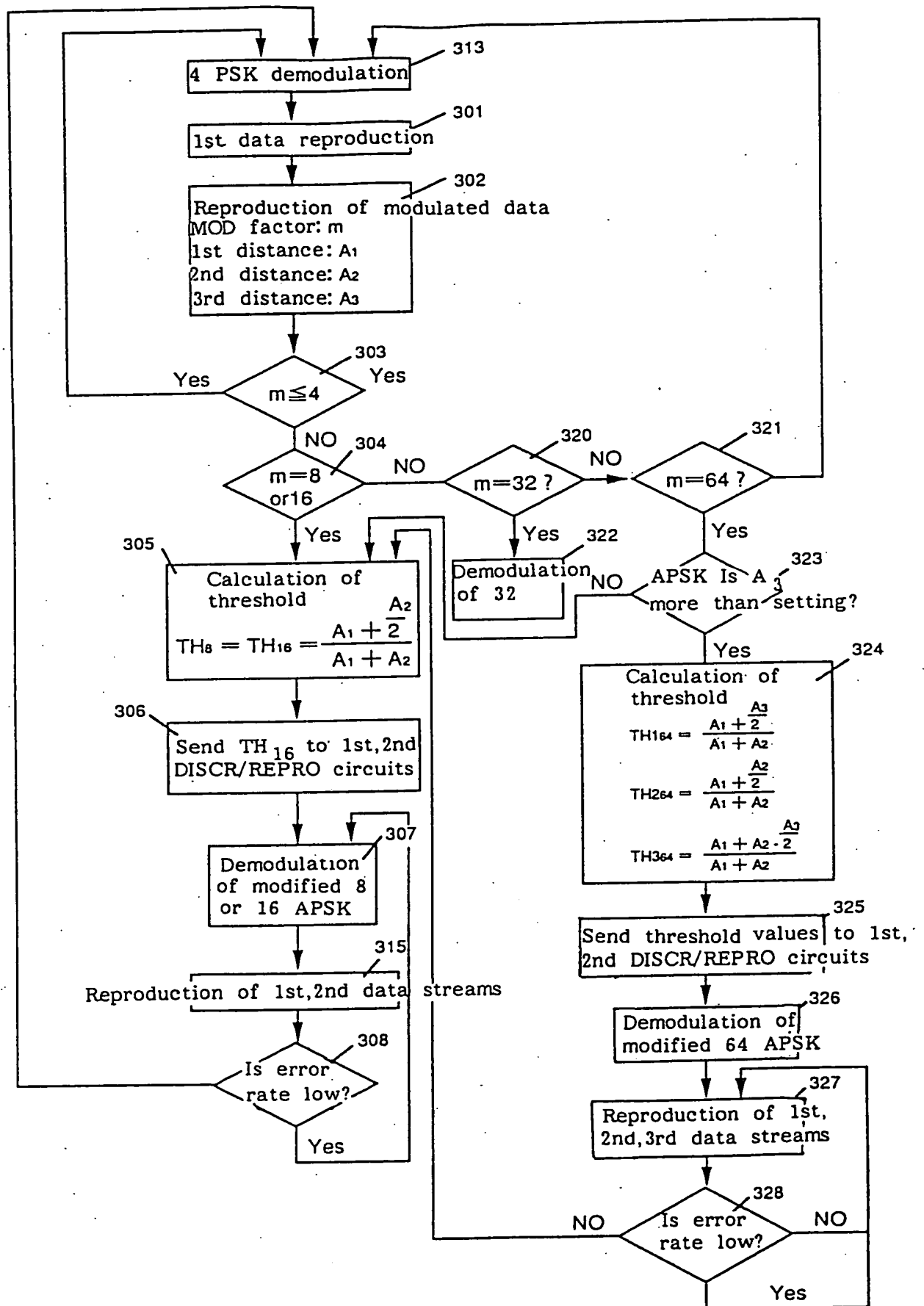


FIG. 29

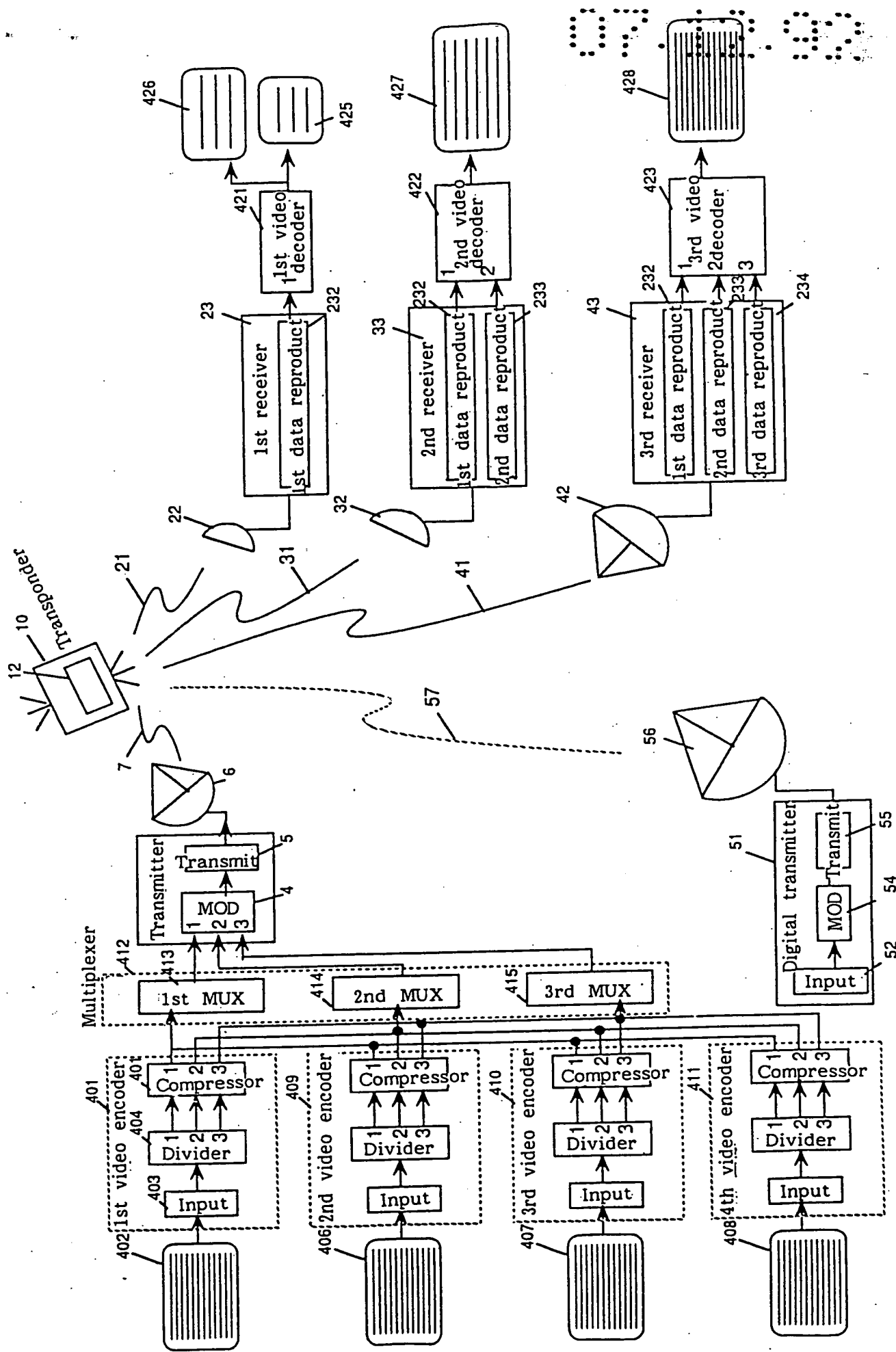
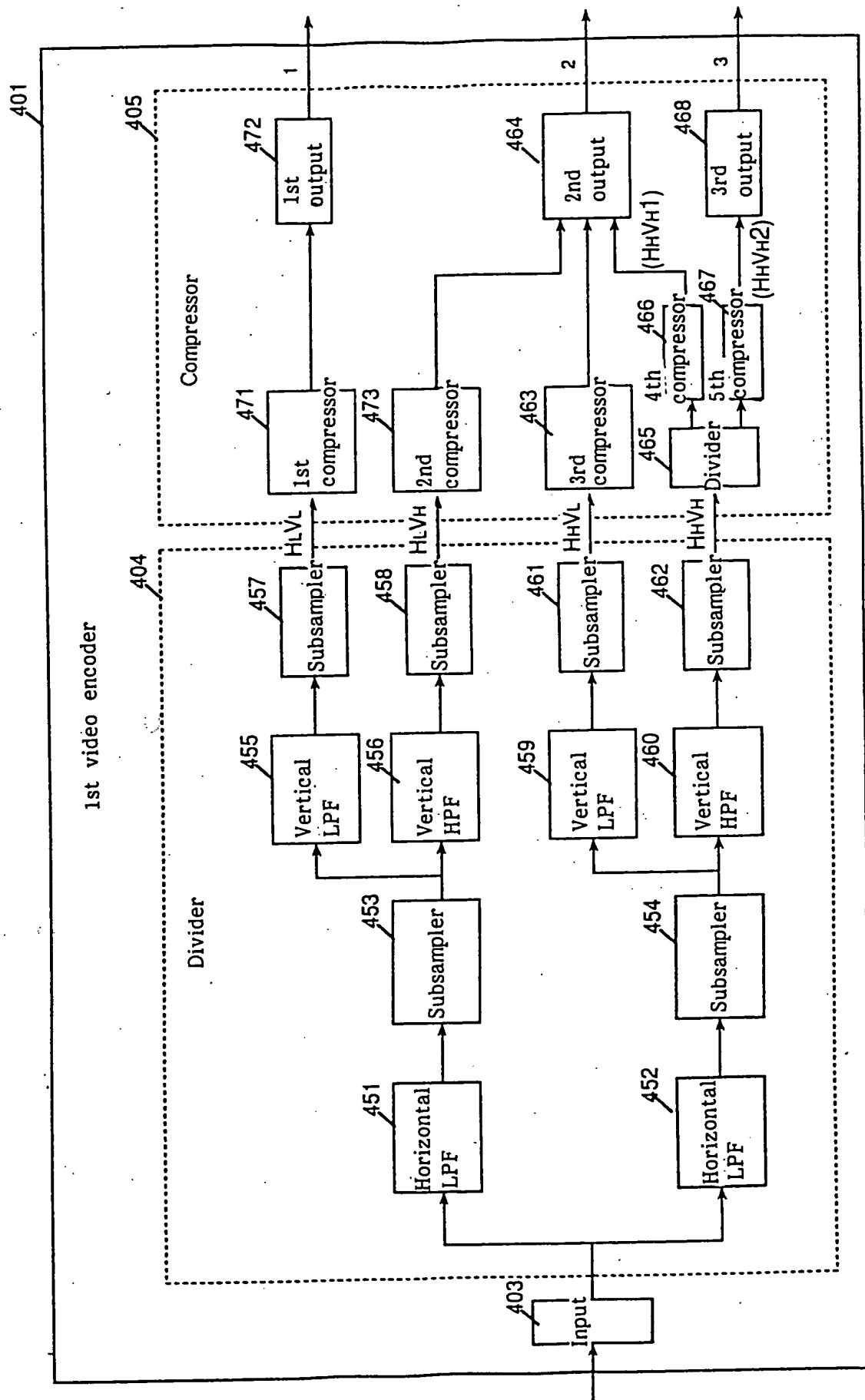


FIG. 30



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FIG. 31

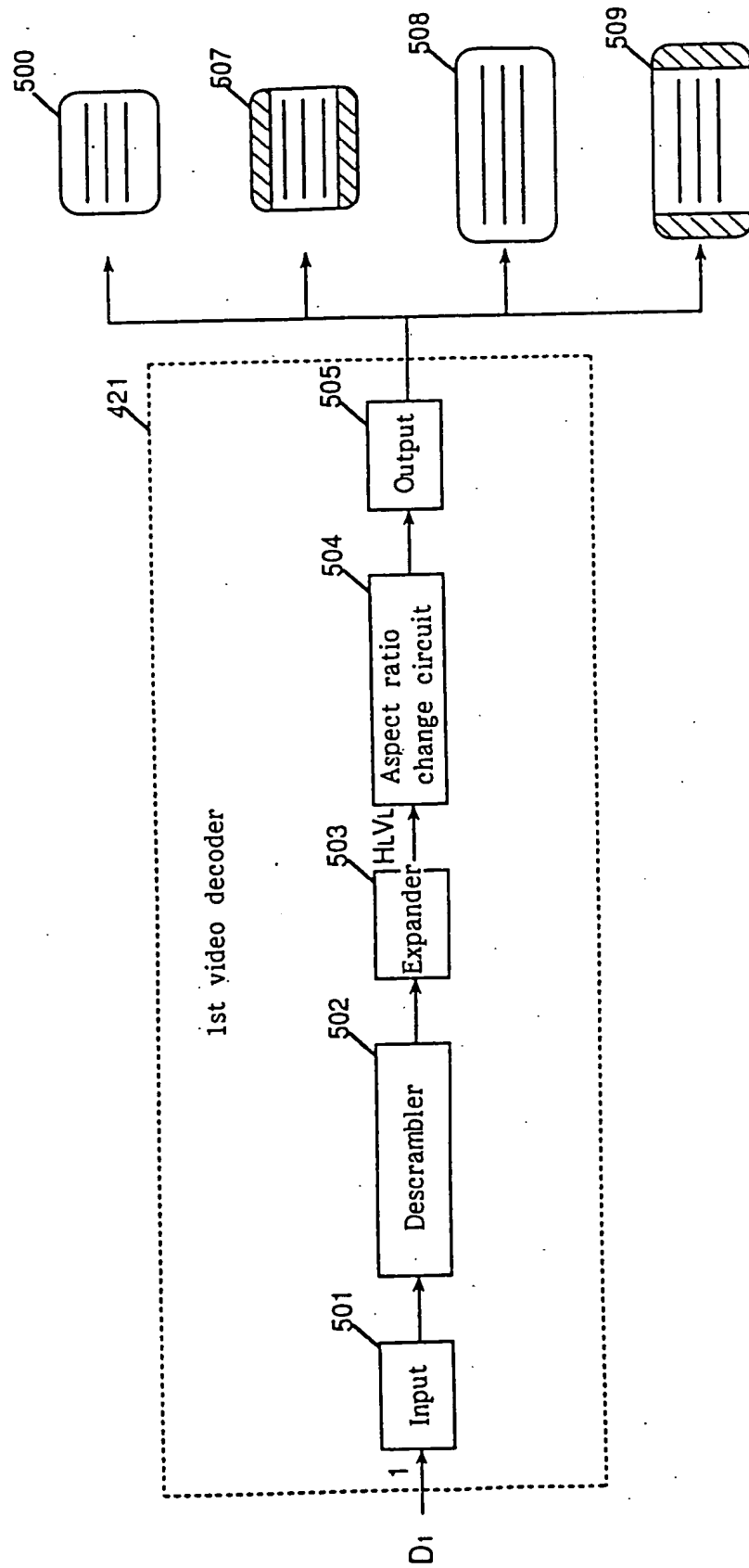


FIG. 32

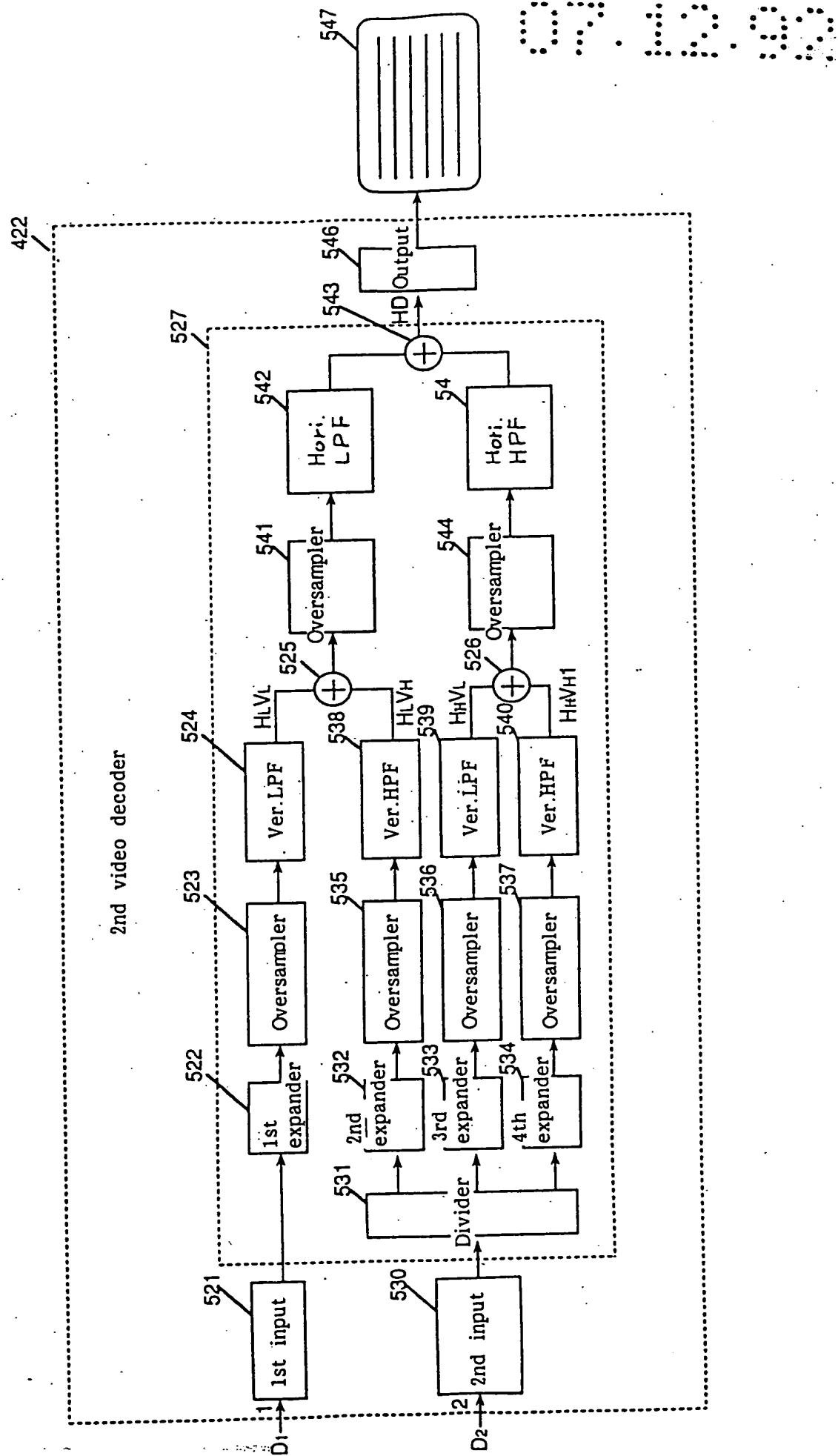
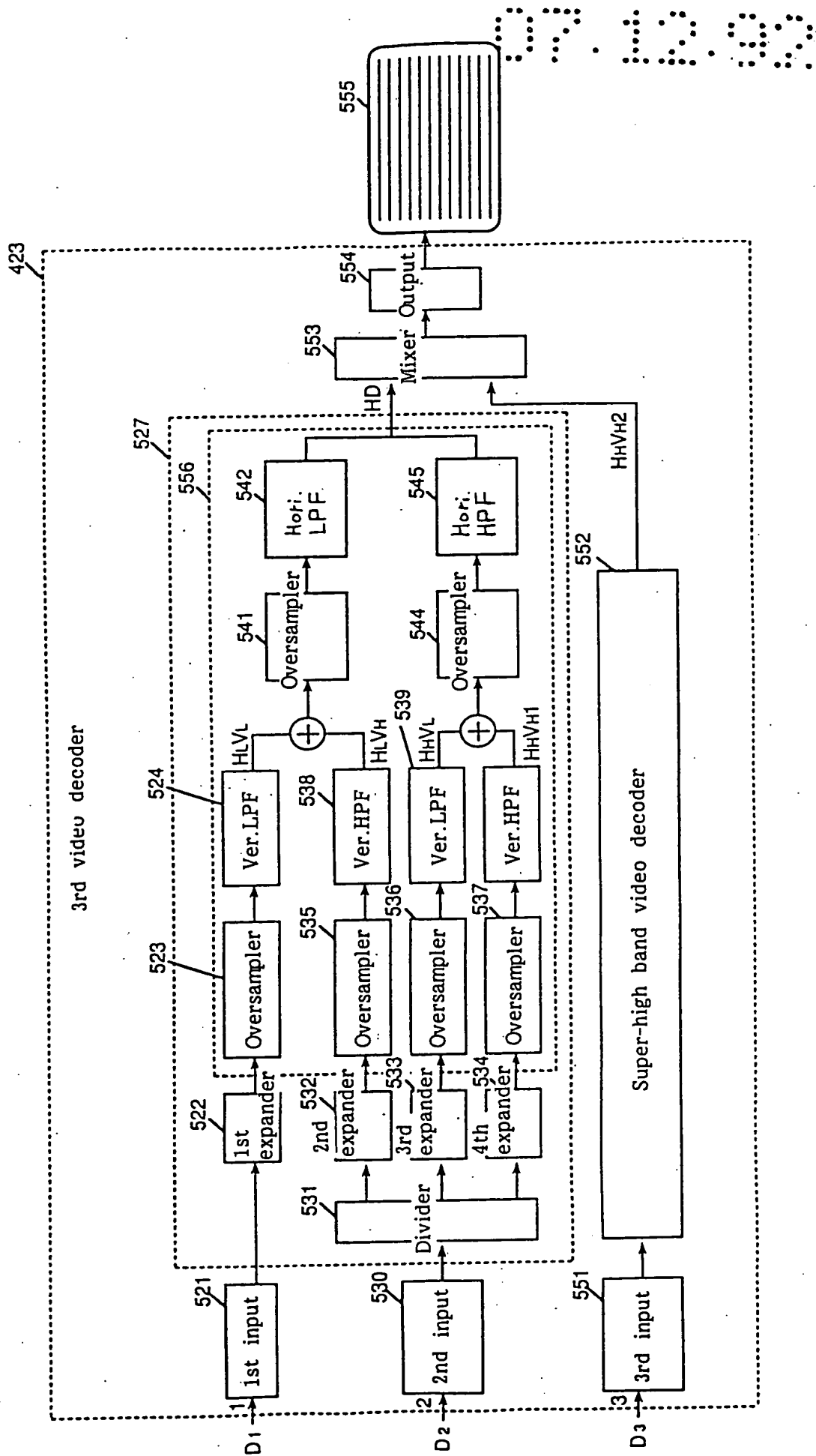


FIG. 33



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FIG. 34

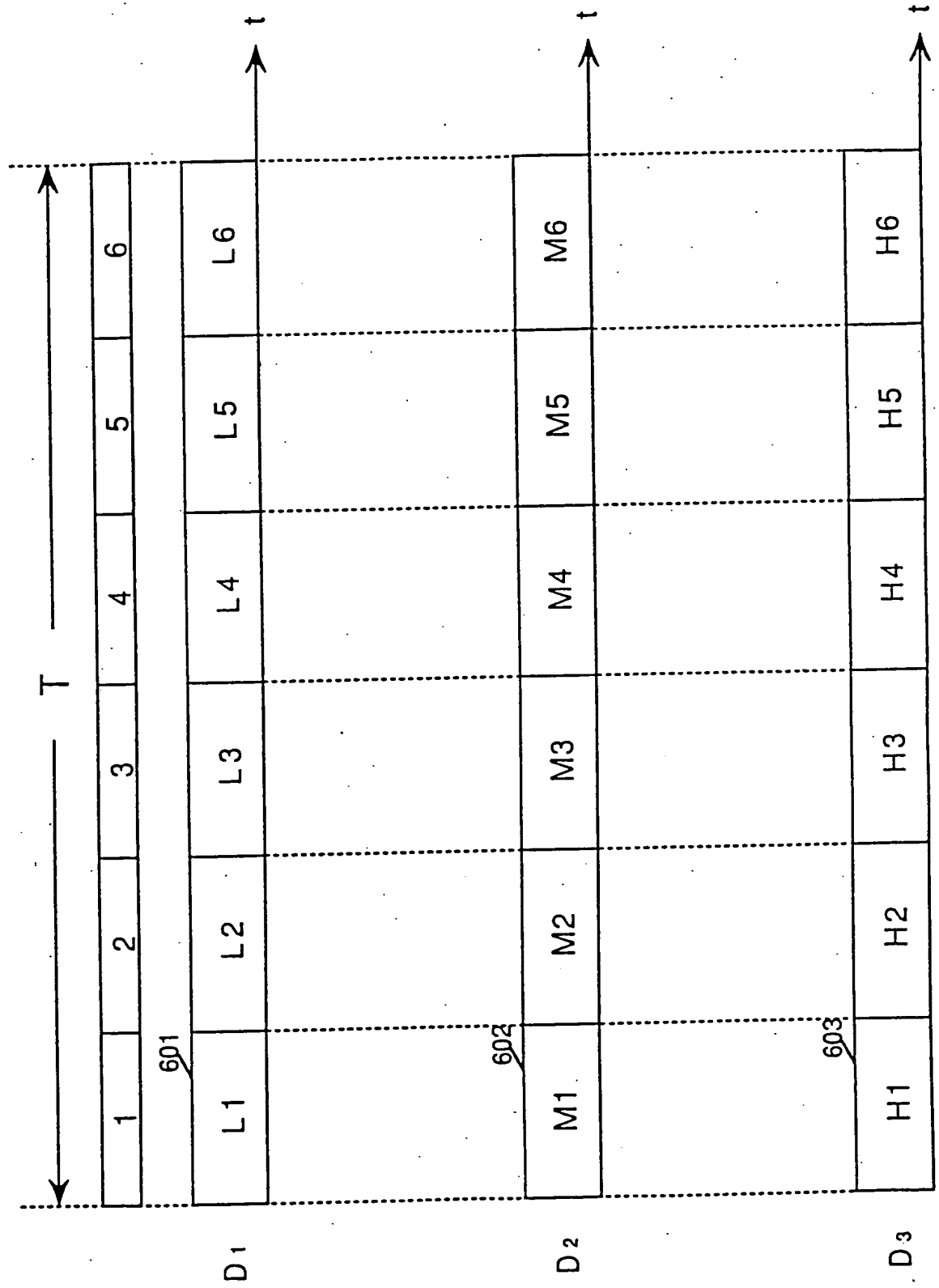
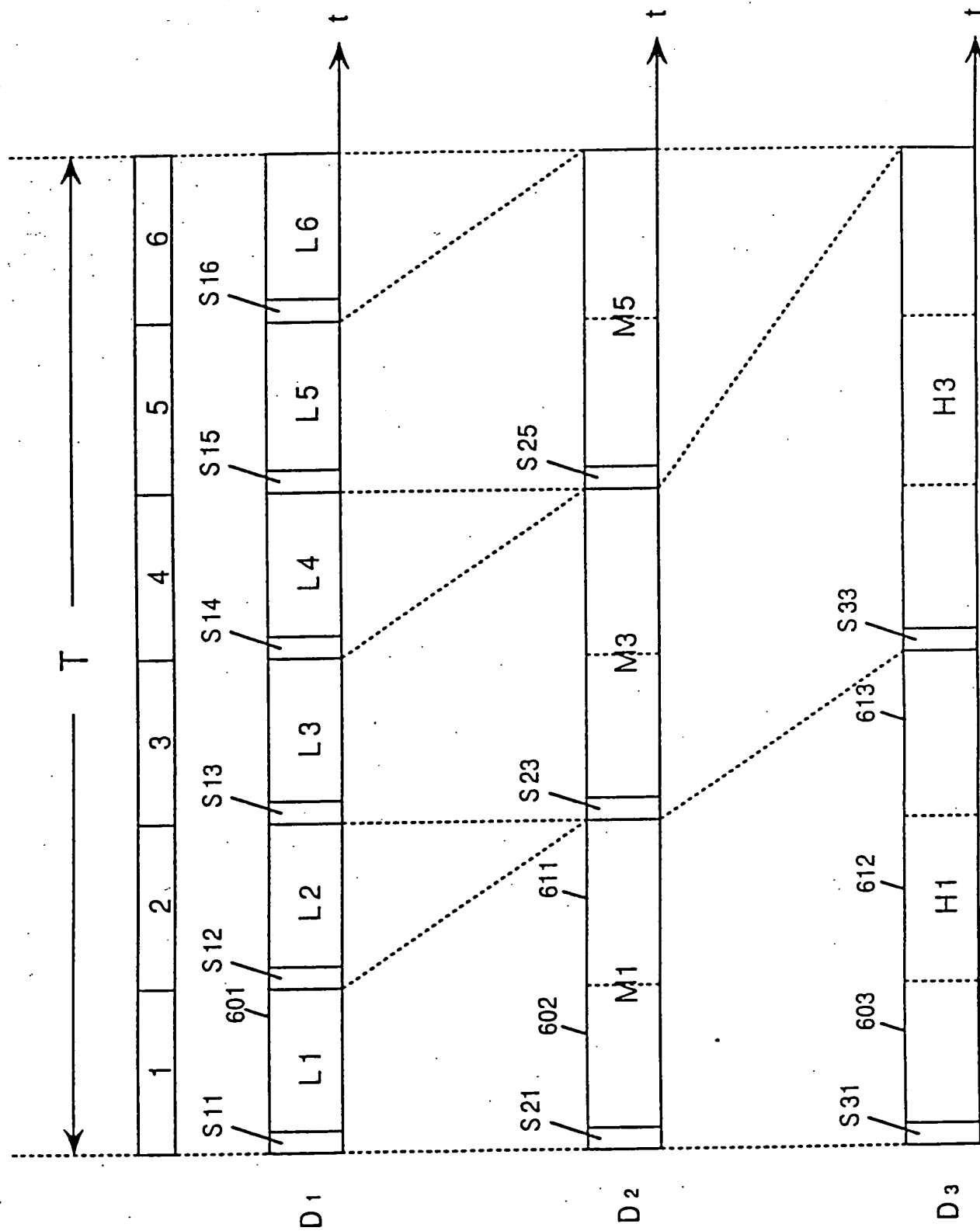


FIG. 35



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FIG. 36

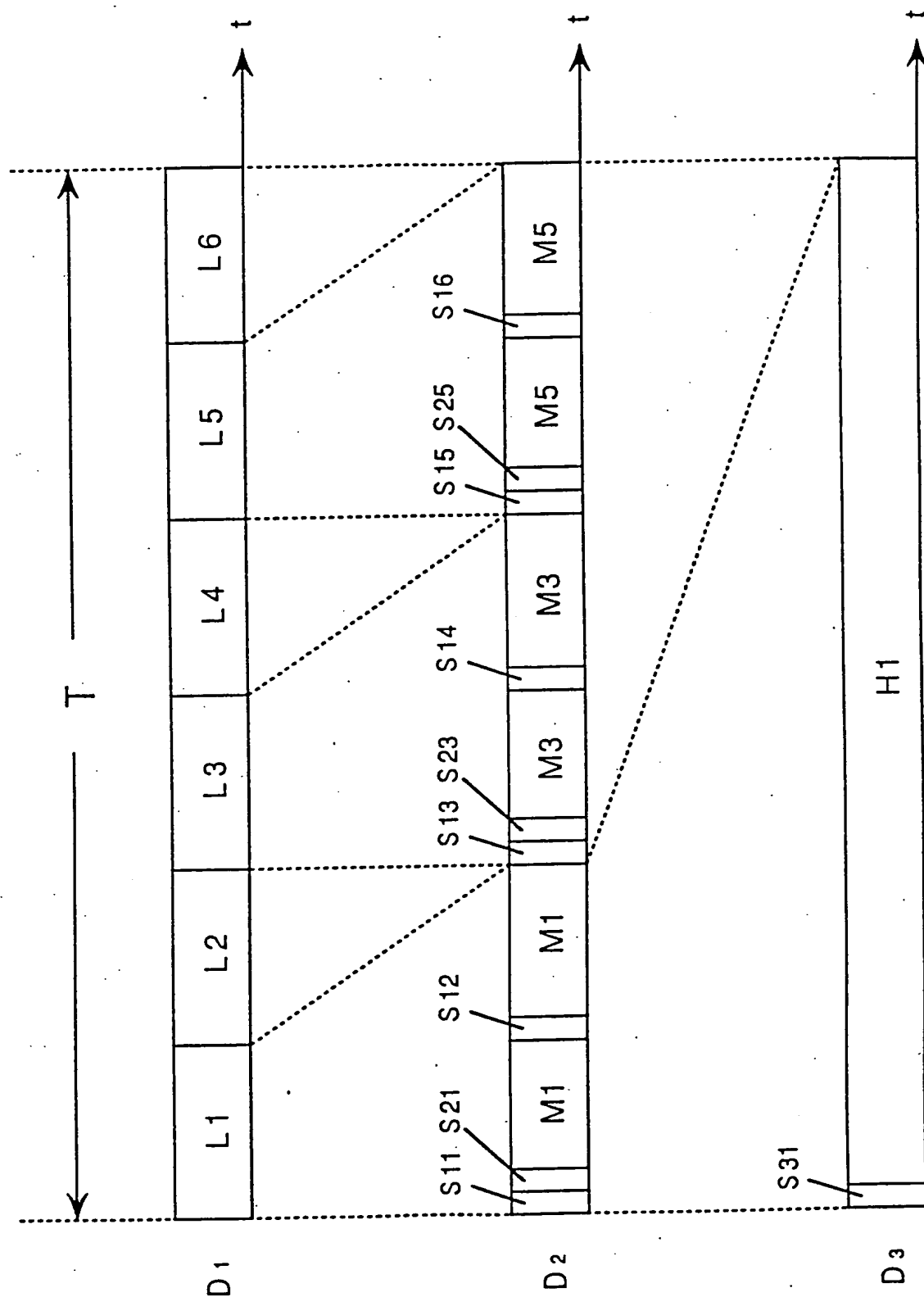
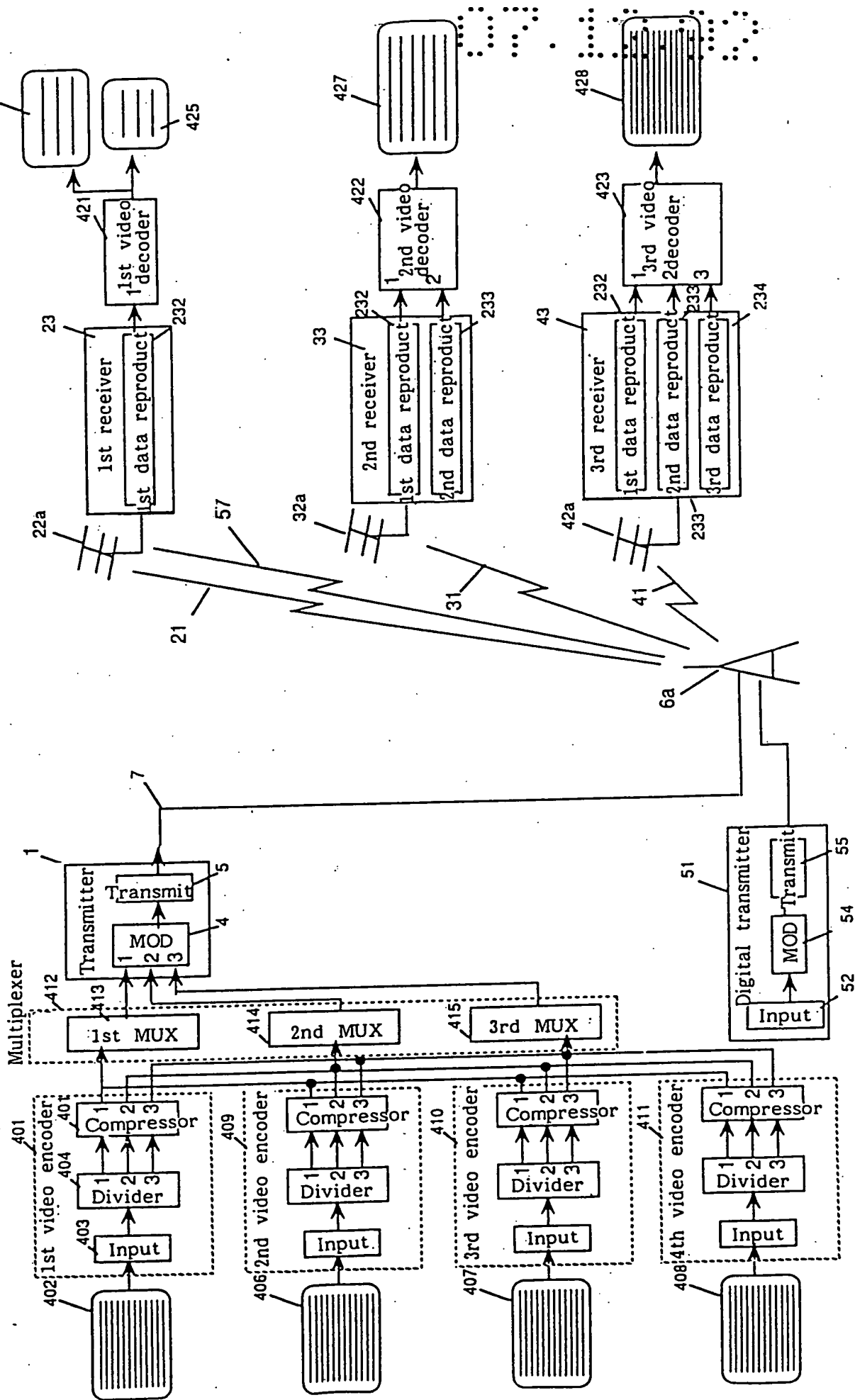
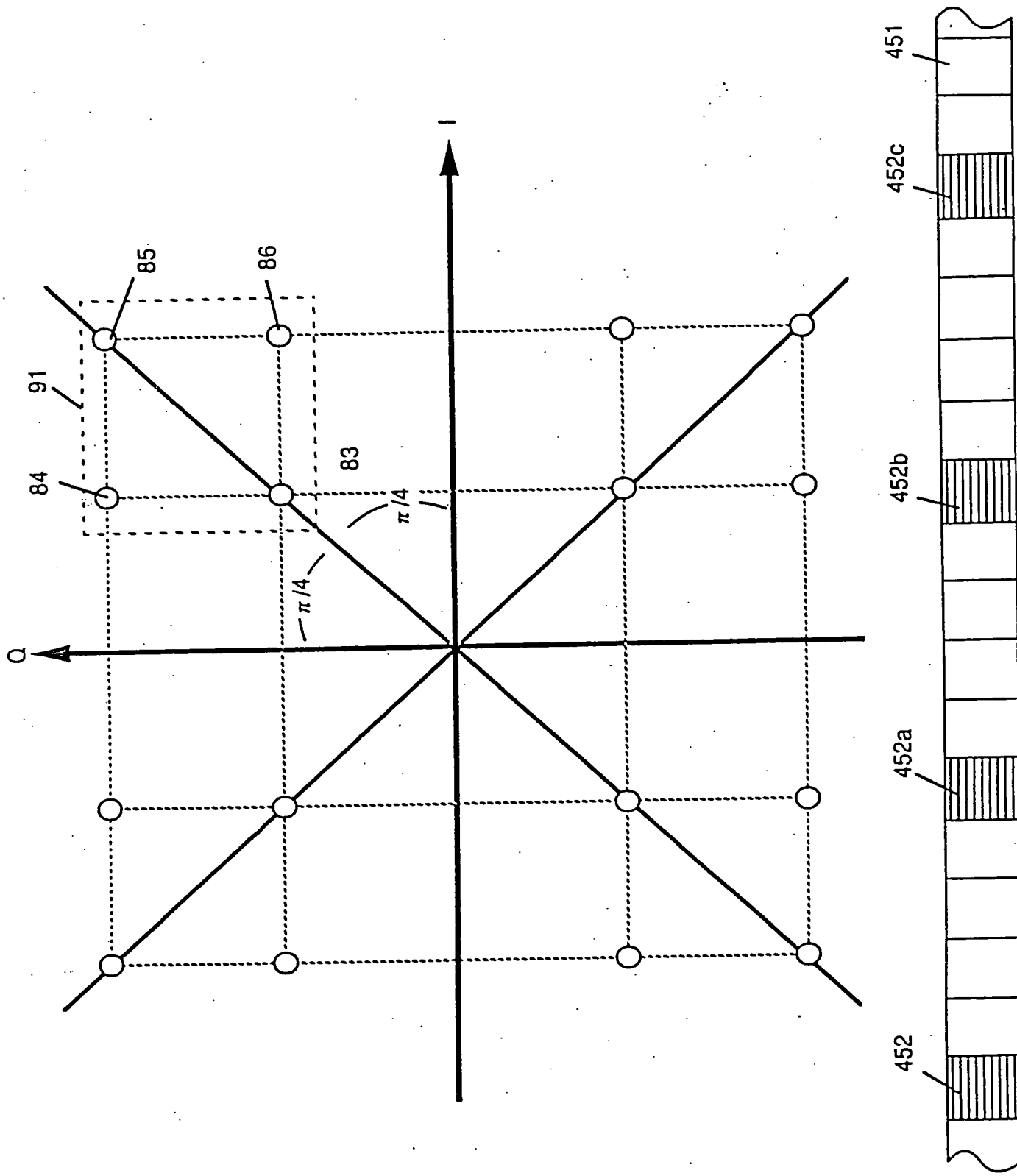


FIG. 37



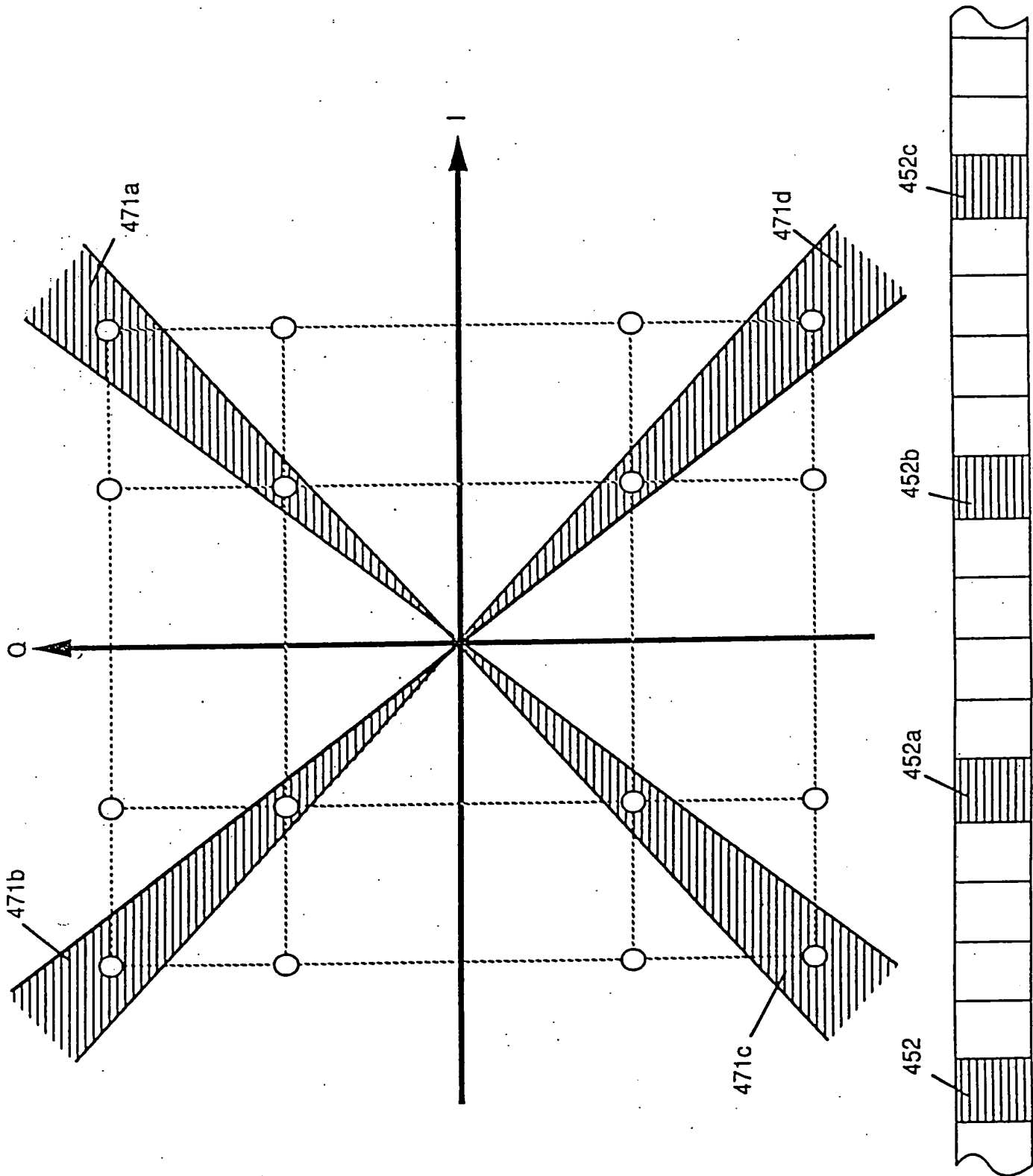
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FIG. 38



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FIG. 39



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FIG. 40

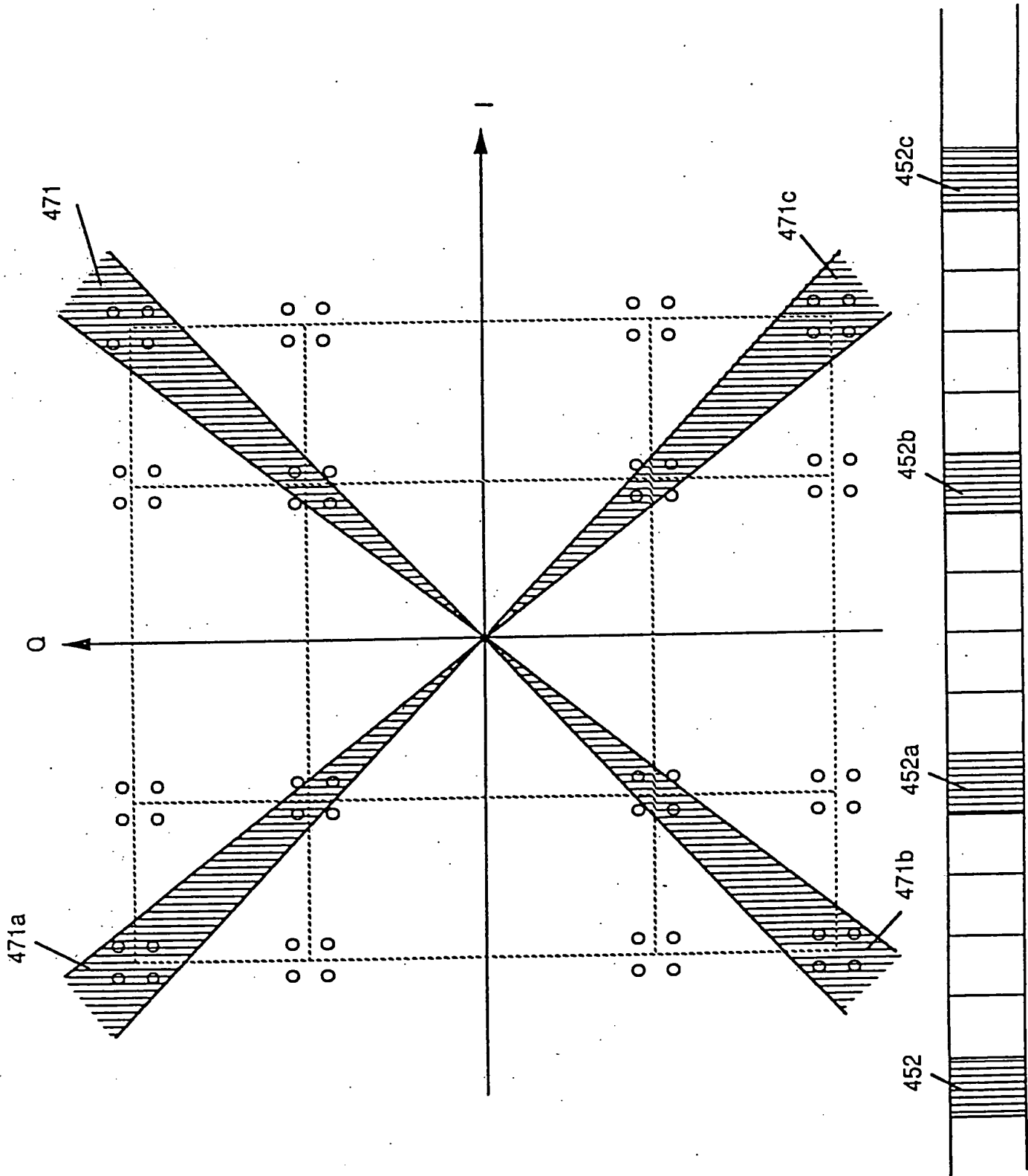


FIG. 42

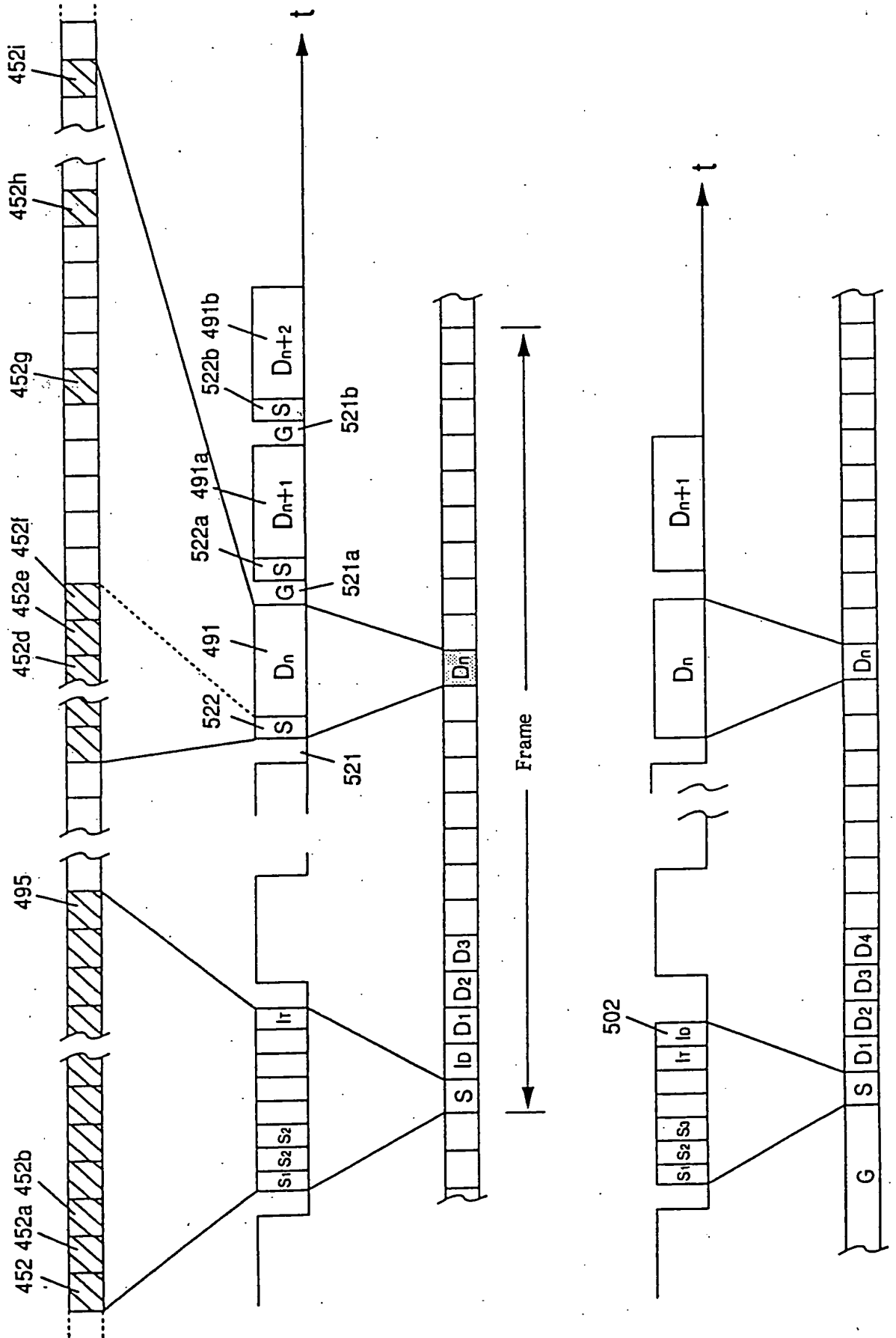


FIG. 43

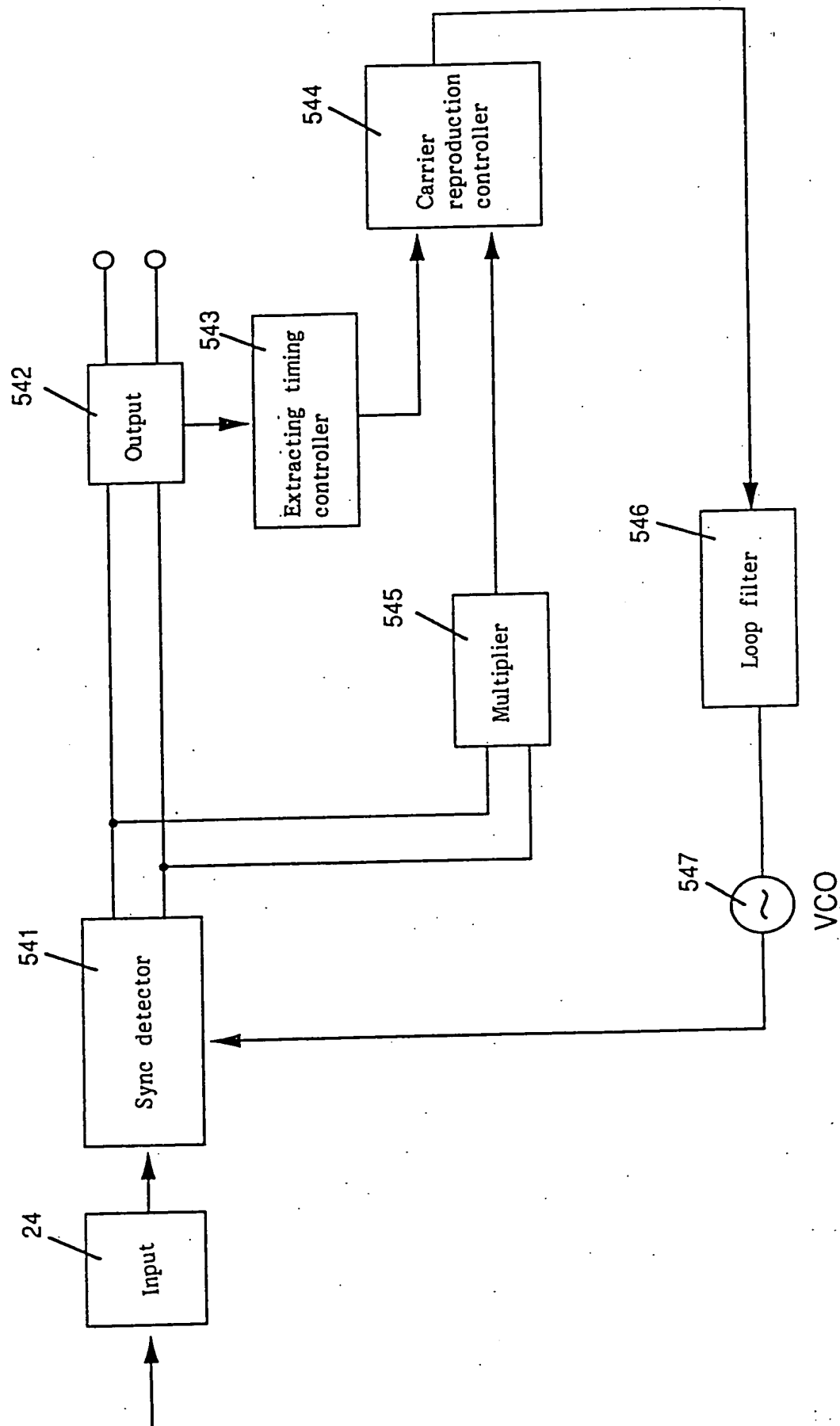
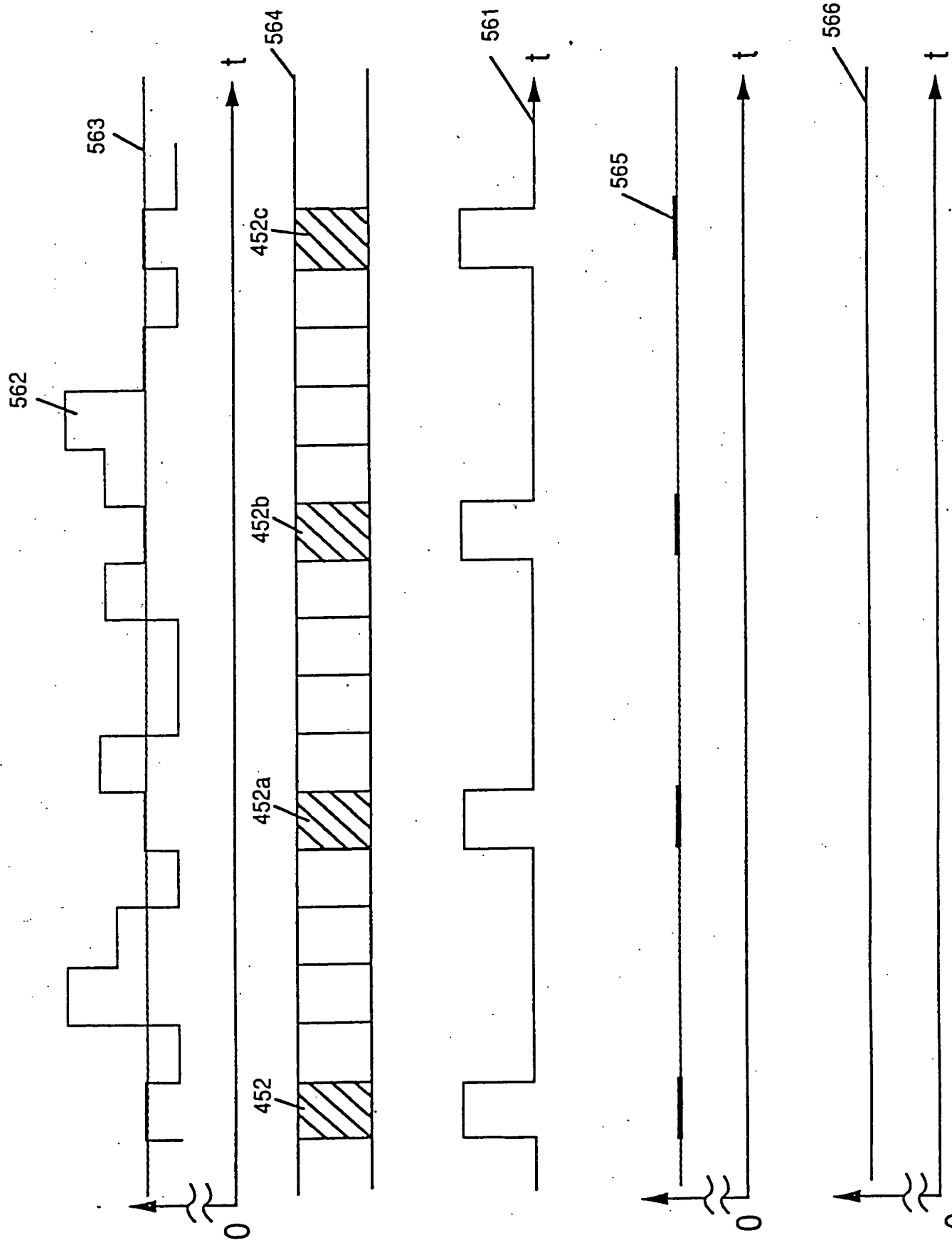
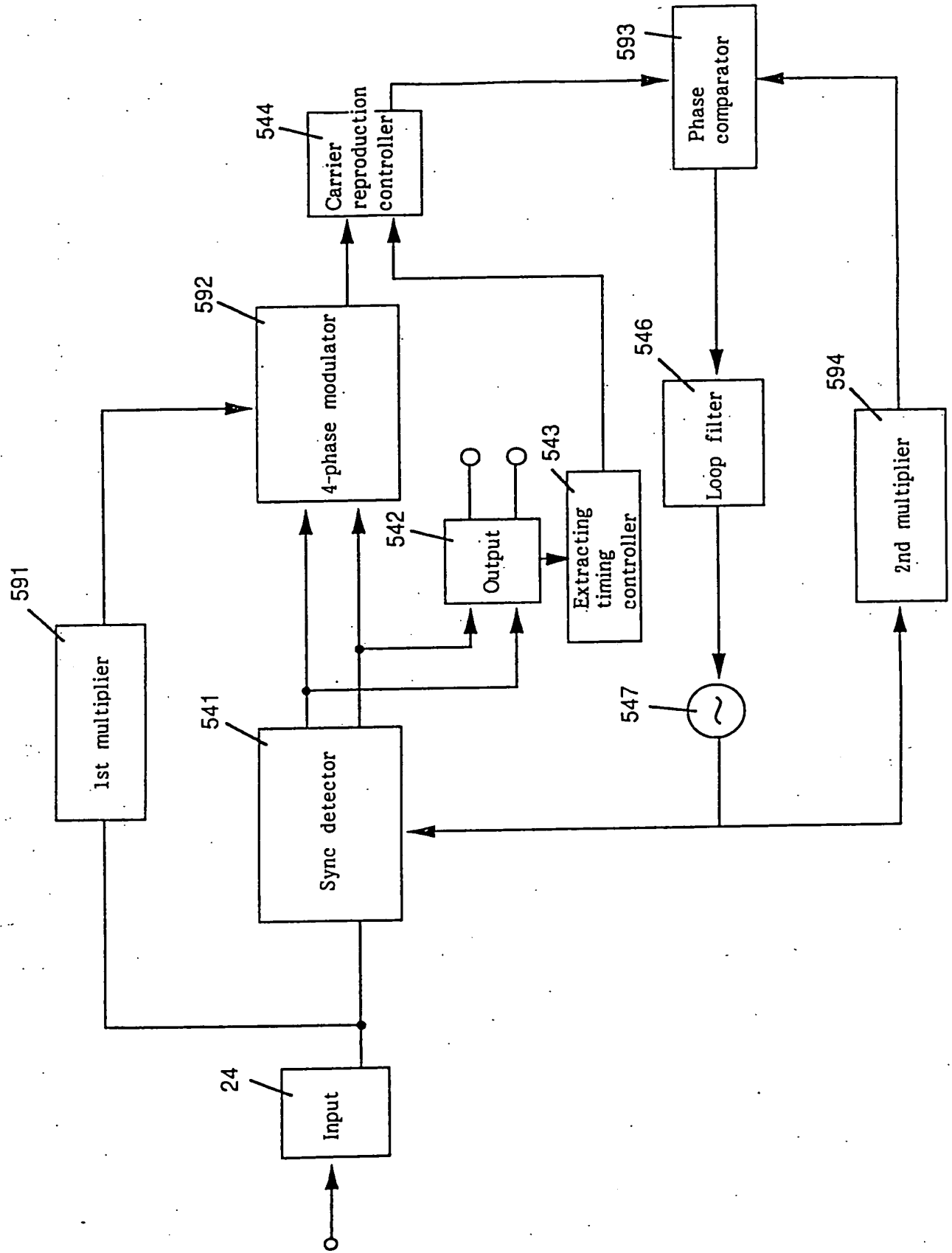


FIG. 44



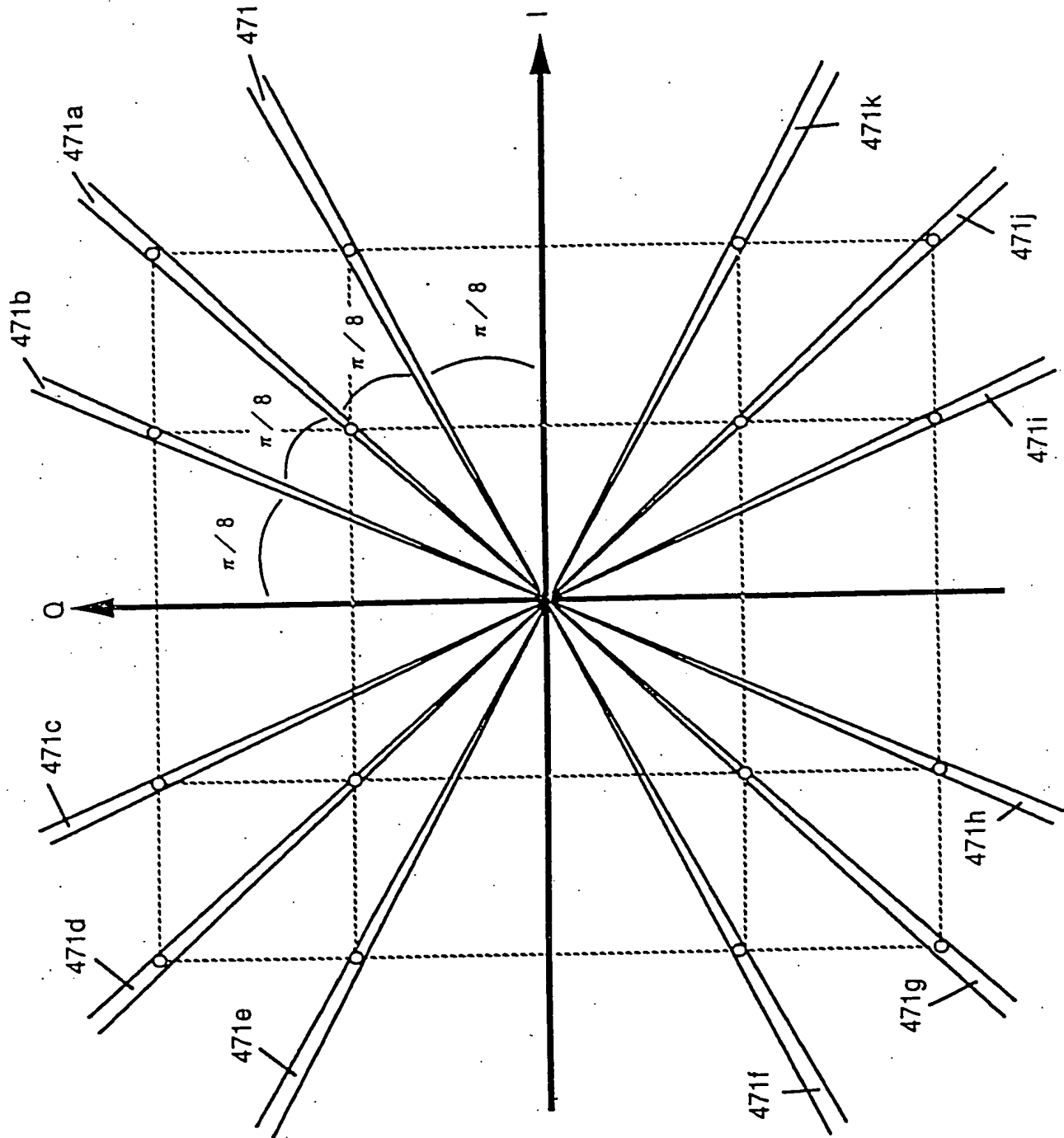
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FIG. 45



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FIG. 46



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FIG. 47

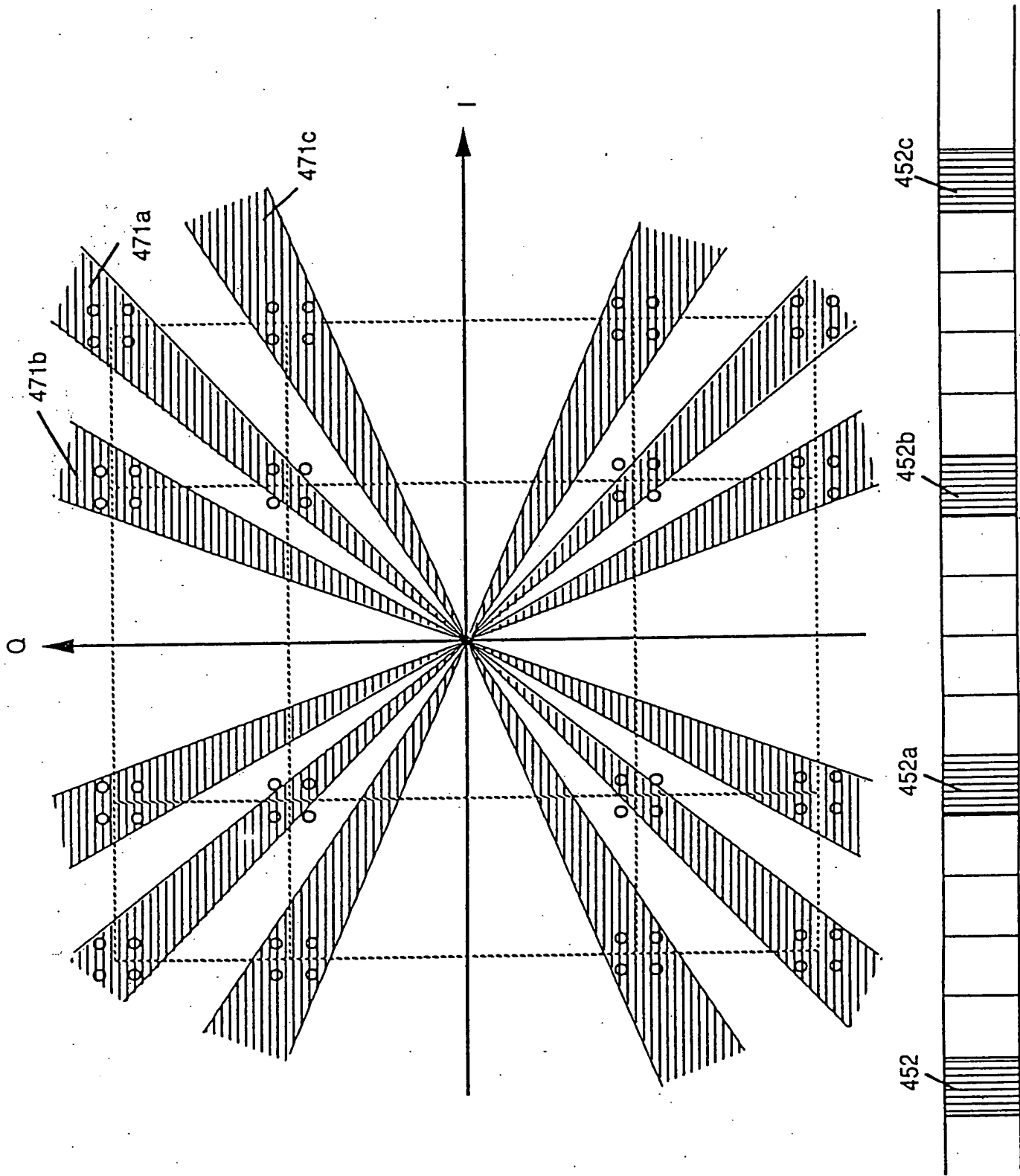


FIG. 48

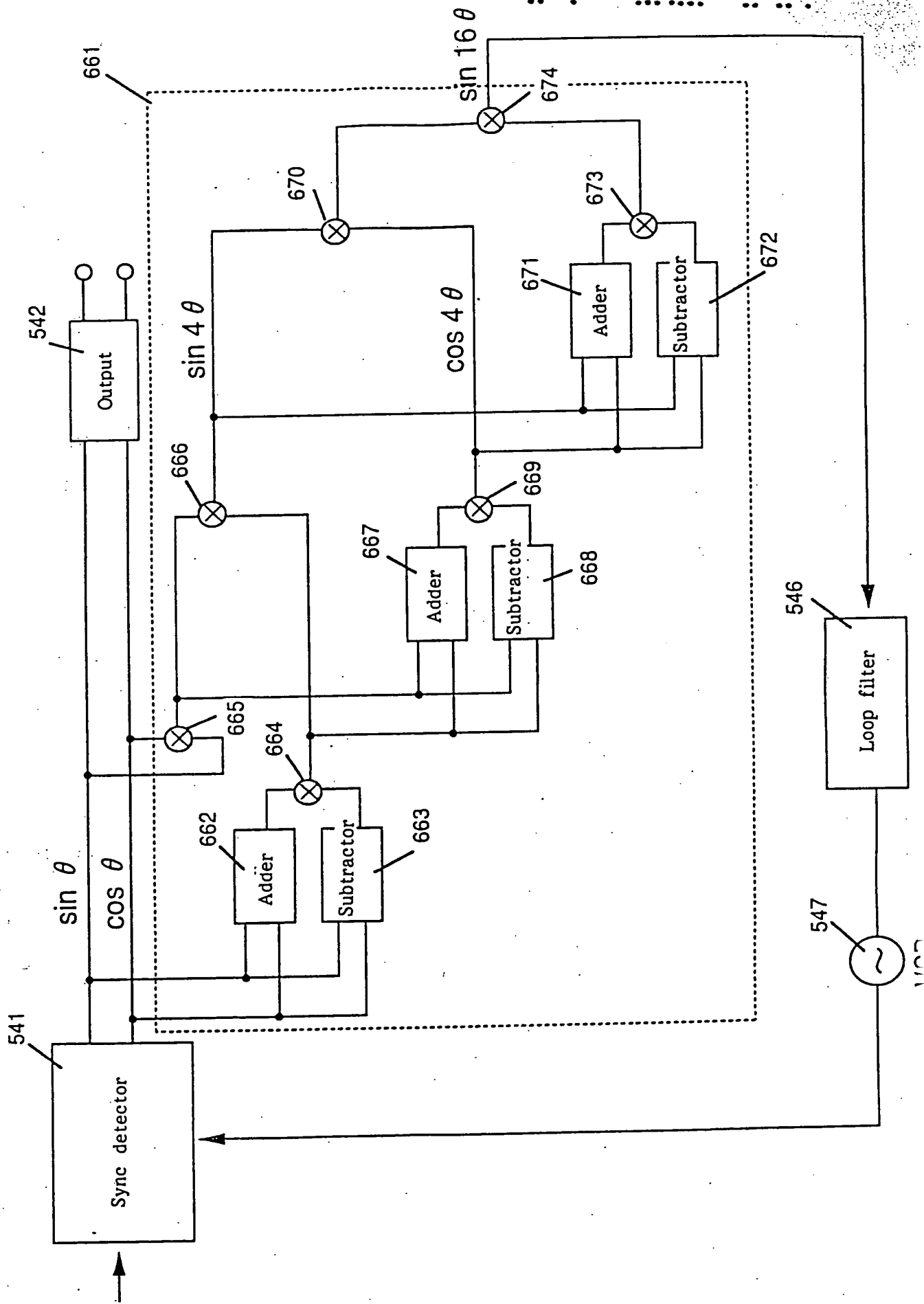


FIG. 49

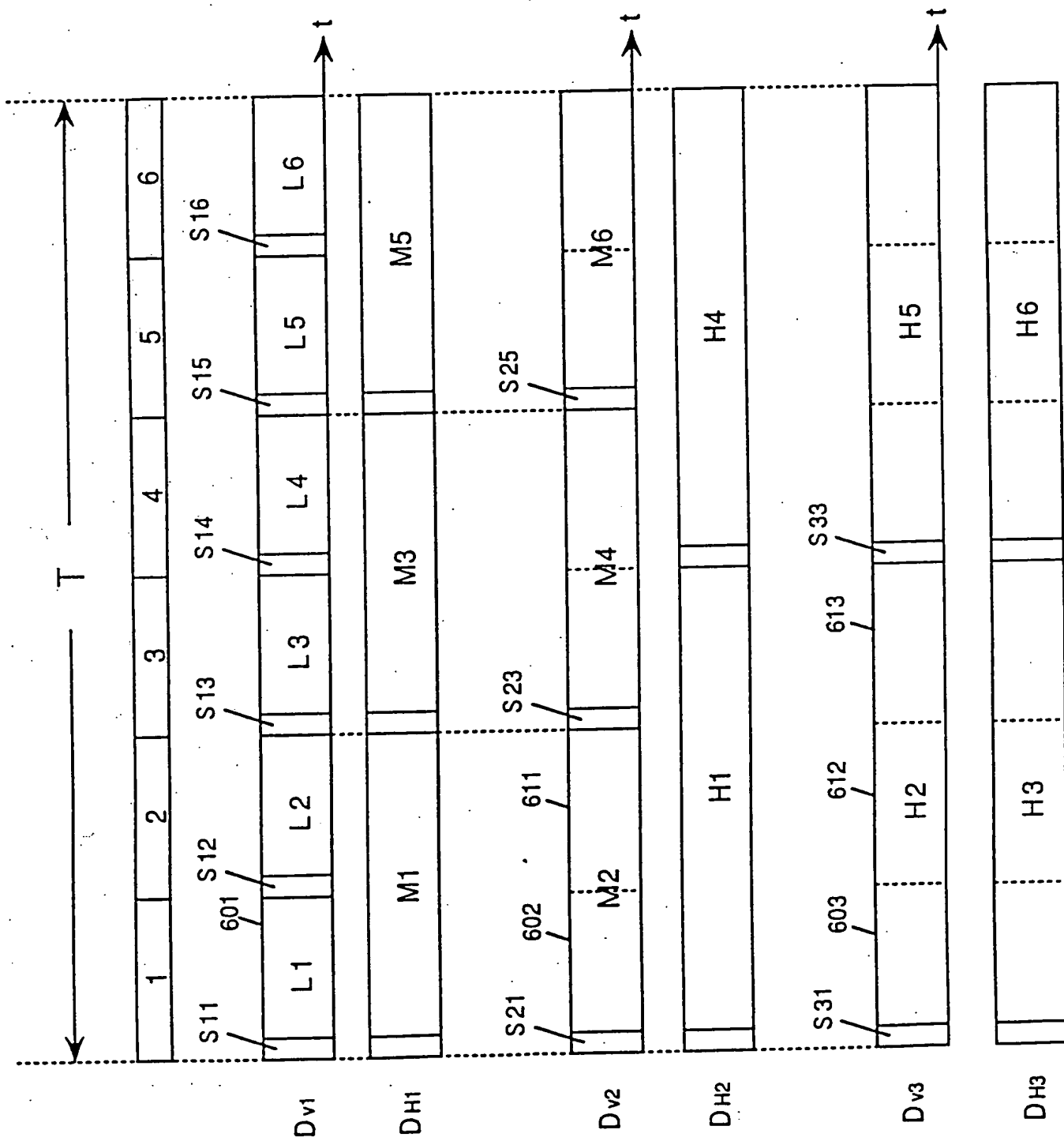


FIG. 50

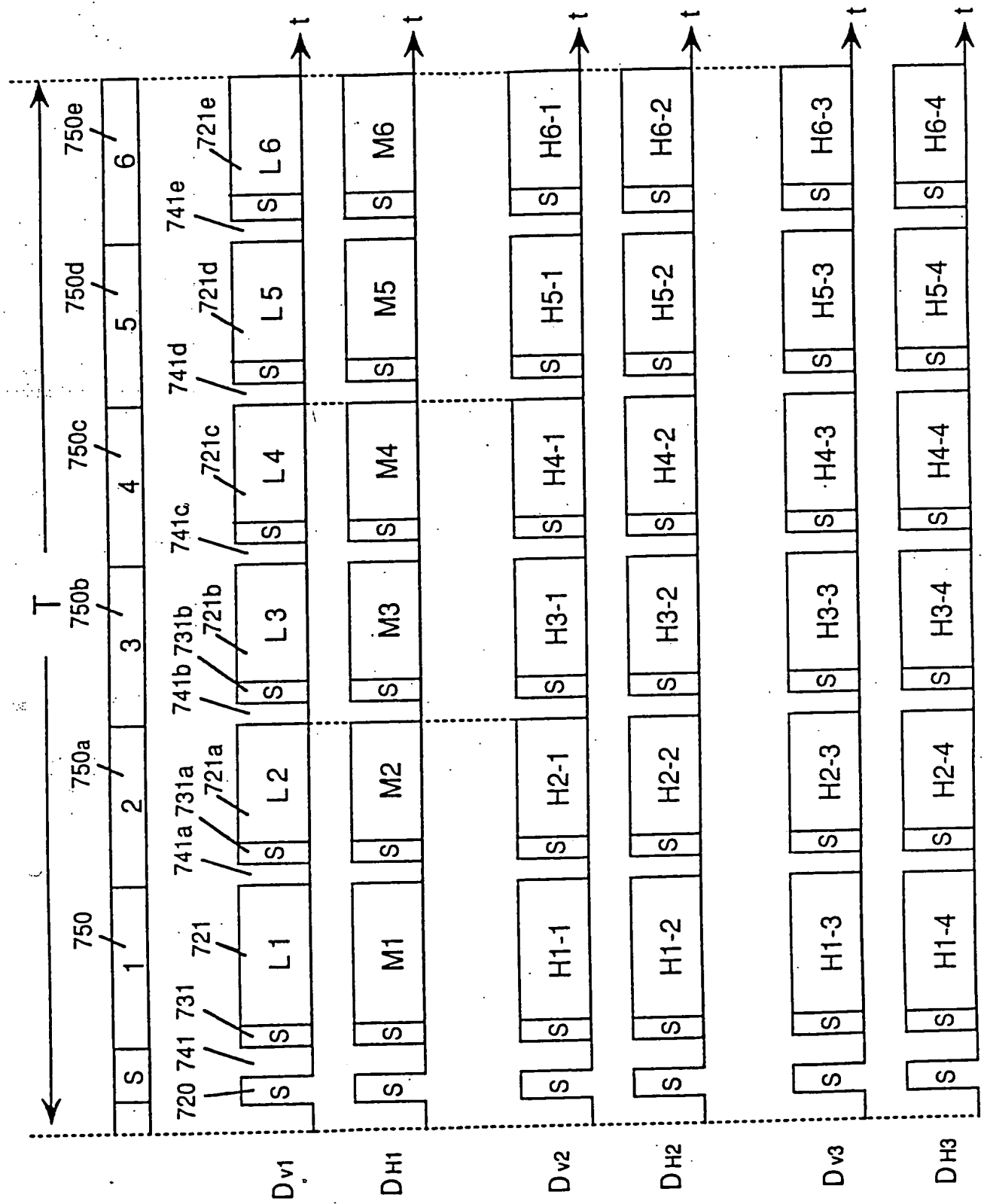
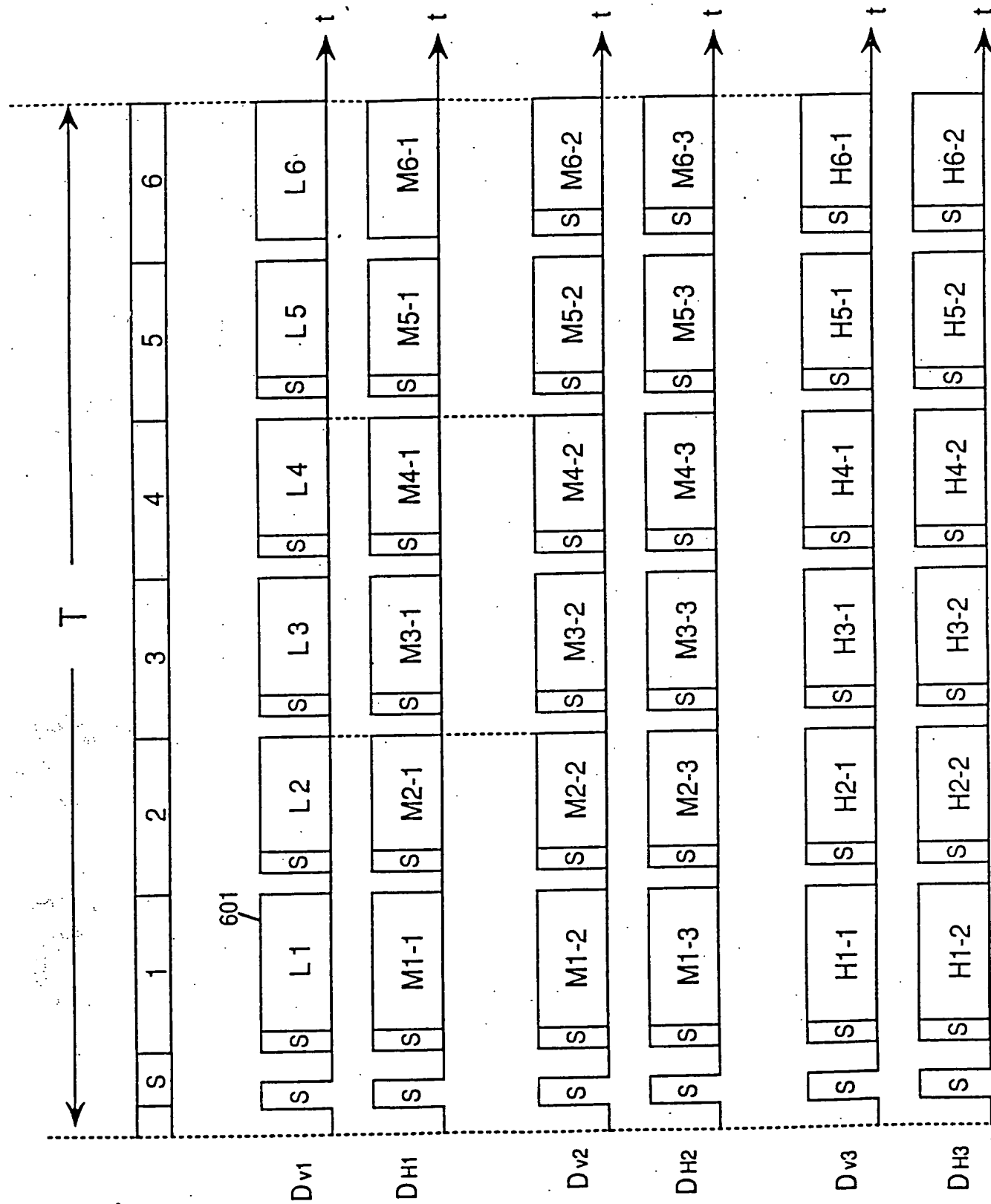


FIG. 51



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[Document name] Abstract of the Disclosure

[Abstract]

[Purpose] To present a signal transmission and reception system capable of transmitting more information in a same frequency band by solving the problem that the transmission information quantity cannot be increased when the frequency band is limited in a signal transmission system for transmitting digital signals.

[Constitution] In a transmitter 1, by a modulator 4 for performing QAM modulation of m values, a first data stream of n values, a second data stream of p values, and a third data stream are assigned with data of n values of the first data stream in the signal point group grouping signal points on the signal space diagram, and a QAM modulation signal of modified m values is transmitted. In a first receiver 23, by a demodulator 25, the first data stream is demodulated, while the first data stream and second data stream are demodulated in a second receiver 23, and the first data stream, second data stream, and third data stream in a third receiver 43, thereby obtaining a signal transmis-

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sion system capable of demodulating data of the first data stream of n values even in a receiver having a demodulation capacity of n values where $n < m$ when receiving a modified multiple value modulation wave of m values.

[Selected drawing] Fig. 1.

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(1)

Document name	Attorney appointment report
File No.	4030425075
Date presented	April 25, 1991
Addressed to	Secretary-General of Patent Office of Japan
Disclosure of the case	
Date filed	Patent petition presented on April 25, 1991
File No.	4030425075
Title of the Invention	Signal transmission system
Filing person	
Relation with the case	Patent applicant
ID number	000005821
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Content reported	
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Patent attorney

Name Akira Kokaji

List of presented documents

Inclusive letter of attorney number 9003129